THE ECOLOGY
OF HONAUNAU BAY, HAWAII

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FINAL REPORT

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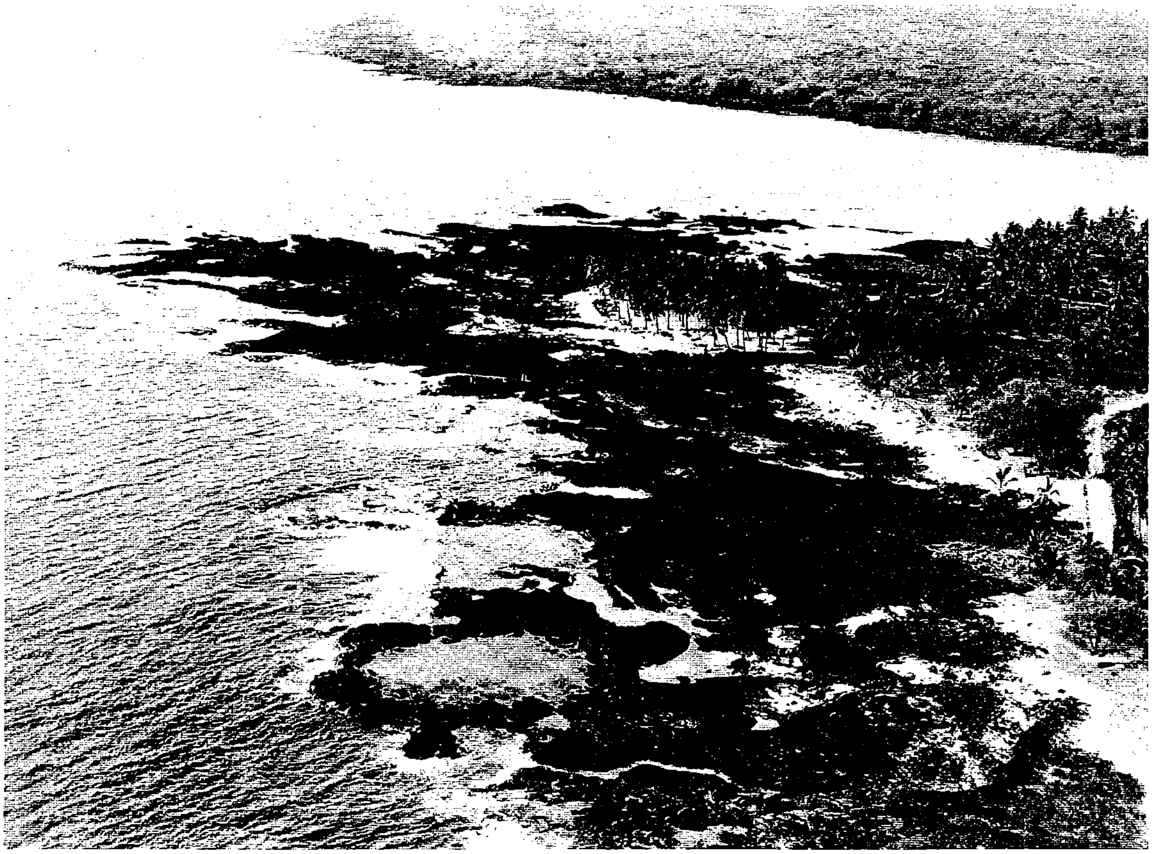

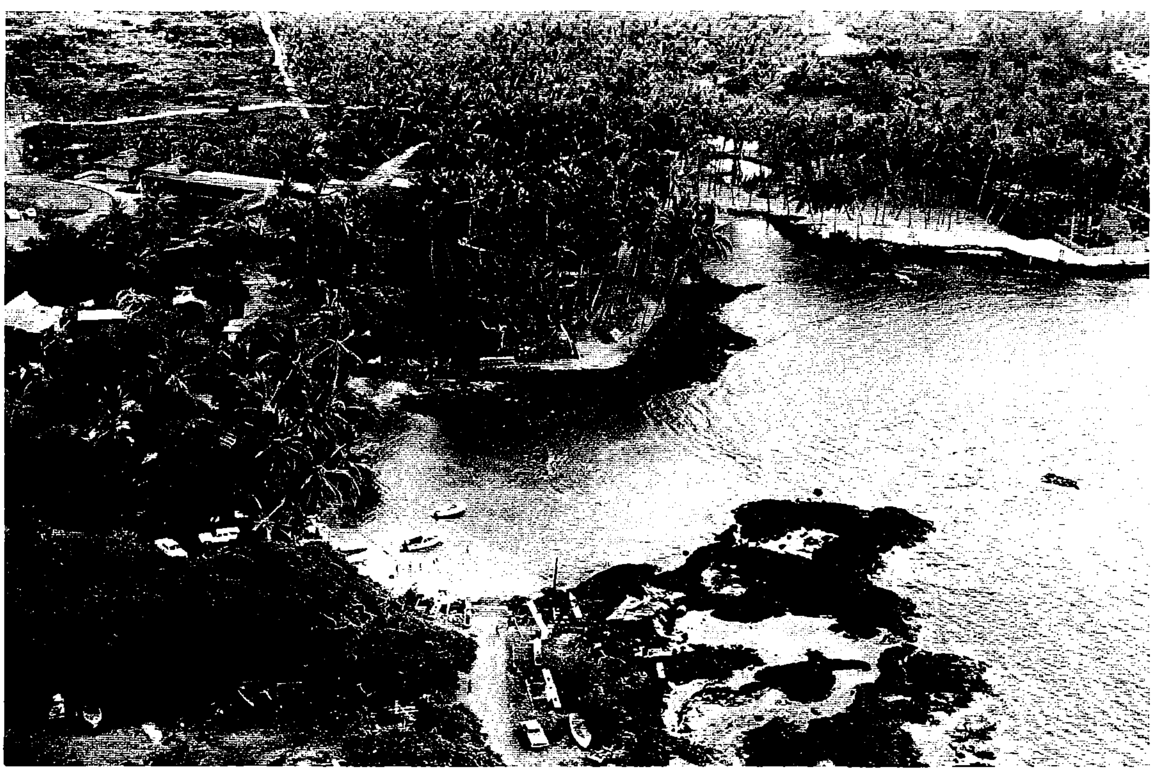

FOREWORD

"Once upon a time" man freely took whatever he desired from the environment. About 10,000 years ago a trend was initiated away from such dependence upon the harvesting of the wild and toward dependence upon domesticated crops. As a result, private rights to property and its produce became established and resources became classified as wild, waste or useful. This describes man's present-day attitudes toward his environmental resources and, in the most general terms, the trend of his thinking.

Today it is recognized that it is the yield of man's renewable resources that will determine, ultimately, the size at which the population of any independent political unit must become stabilized. Renewable resources are those that can be harvested and yet continue to yield at some sustained production rate—a property generally restricted to living systems. The limits of maximum sustained yield are being approached for the renewable resources of the land classified as useful, and man is being forced to exploit areas formerly considered waste or wild, including those of the sea.

With the explosive increase in human populations, the view that wild resources are "common property" for anyone and everyone to take must change. All resources, wild included, must be used to the optimal public benefit; such benefit being defined to include esthetic, recreational, health, academic and commercial values.

Public concern over problems of the classification and use of land areas under the pressures of expanding populations is becoming great, whereas as yet apathy and neglect have been typical of the public attitude towards use of the sea. Thus far concern has been reserved chiefly for single purpose usages of shallow waters such as for harbors, resorts, marine parks or for waste disposal.

In Hawaii most of the protected accessible shore areas have been greatly altered in recent time. Therefore, it is critical that the few remaining in a relatively pristine condition be studied to determine their real value beyond that which is readily apparent. Much information is required in order to plan for the maximum long-term usage of a resource. Since resources such as bays and other usable marine areas are scarce in Hawaii, multiple purpose use must be considered.

Honaunau Bay lies adjacent to the City of Refuge National Historical Park and indeed is an integral part of its setting. However, at the present time the bay is totally unprotected. Visitors to this area have doubled nearly three times in the last five years, and this rate shows signs of further acceleration. The trend toward pollution of the bay has already been initiated by undesirable practices. The following text is a collection of scientific data, results and conclusions essential to the Park Service in preventing this contamination while at the same time developing the region for maximum public use.

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INTRODUCTION

This report has been prepared pursuant to contract number 14-10-9-900-136 of the fiscal year 1969 between the Research Corporation of the University of Hawaii and the National Park Service, U.S. Department of the Interior. The work was coordinated in the Botany Department of the University of Hawaii. The contract was awarded to conduct studies of the ecology of Honaunau Bay, City of Refuge National Historical Park, under the authority of 16 U. S. C. 462: Historic Sites, Building, Objects and Antiquities.

Honaunau Bay is located (19° 25' N; 155° 55' W) on the Kona (leeward) Coast of the island of Hawaii. It lies on the western slope of Mauna Loa approximately 6 miles south of the edge of Hualalai Volcano. The information in the present text was provided by a specially constituted advisory group whose studies of Honaunau Bay were organized around the following areas of investigation:

1 - geography and physical nature of Honaunau Bay and its setting;

2 - hydrography, the chemical and physical nature of the water in Honaunau Bay;

3 - development of hypotheses concerning the biological interrelationships between land and sea at present;

4 - determination of the distribution, abundance and nature of the predominant and special organisms, including

- a) seaweeds,
- b) plankton and microorganisms,
- c) corals,
- d) mollusks,
- e) crustacea,
- f) echinoderms,
- g) fish (being done in collaboration with the State Division of Fish and Game fish monitoring program);

5 - analysis of the present populations of the above mentioned organisms in reference to environmental conditions in

order to predict likely patterns of change in these populations with intensifying human activity;

6 - formulation of recommendations for the preservation of the biota and waters of Honaunau in their present state.

The extent of investigation (Fig. 1) was from Miana Point at the north extremity of Honaunau Bay to the southern tip of Alahaka Bay. However, for comparative purposes some material presented here concerns neighboring bays, principally Kealakekua Bay located 2.5 miles north of Honaunau Bay.

As the study progressed the work became adapted to the special conditions at Honaunau Bay. For instance, due to the inconspicuous role played by algae, bivalve mollusks and crustacea, little work was done with these organisms. When one regards the general character of the bay, it is not surprising to find these, respectively, high inorganic fertilizer utilizers and detritus feeders inconspicuous. Emphasis was increased accordingly on the showpieces of Honaunau Bay, the corals, vertebrates, gastropod mollusks and echinoderms.

Foremost among the people who contributed time and effort to this study was the late Mr. Fred Weld, assistant to the coordinator. He headed the majority of field work and contributed to the advisory committee the majority of manuscripts constituting this ecological study.

Chapter 9 on mollusks was contributed by Dr. E. Alison Kay, Department of General Science, University of Hawaii. The material in Chapter 2, Geology, was largely written by Dr. Gordon A. Macdonald, Department of Geosciences, University of Hawaii. Chapter 8 on coral was contributed by Mr. Eric Preston, Department of Zoology, University of Hawaii. Chapter 10 on sea urchins was contributed by Mr. Donald Kelso, Department of Zoology, University of Hawaii. Dr. Charles H. Lamoureux, Department of Botany, University of Hawaii, contributed a significant portion of Chapter 14 on vascular plants.

Mr. Michio Takata receives our special thanks for directing the monitoring of fish populations an activity which could well be extended to other groups of dominant organisms. For similar reasons appreciation is expressed to Mr. Ralph H. Tanimoto, Department of Health, State of Hawaii, who made the microbiological assays available; and to

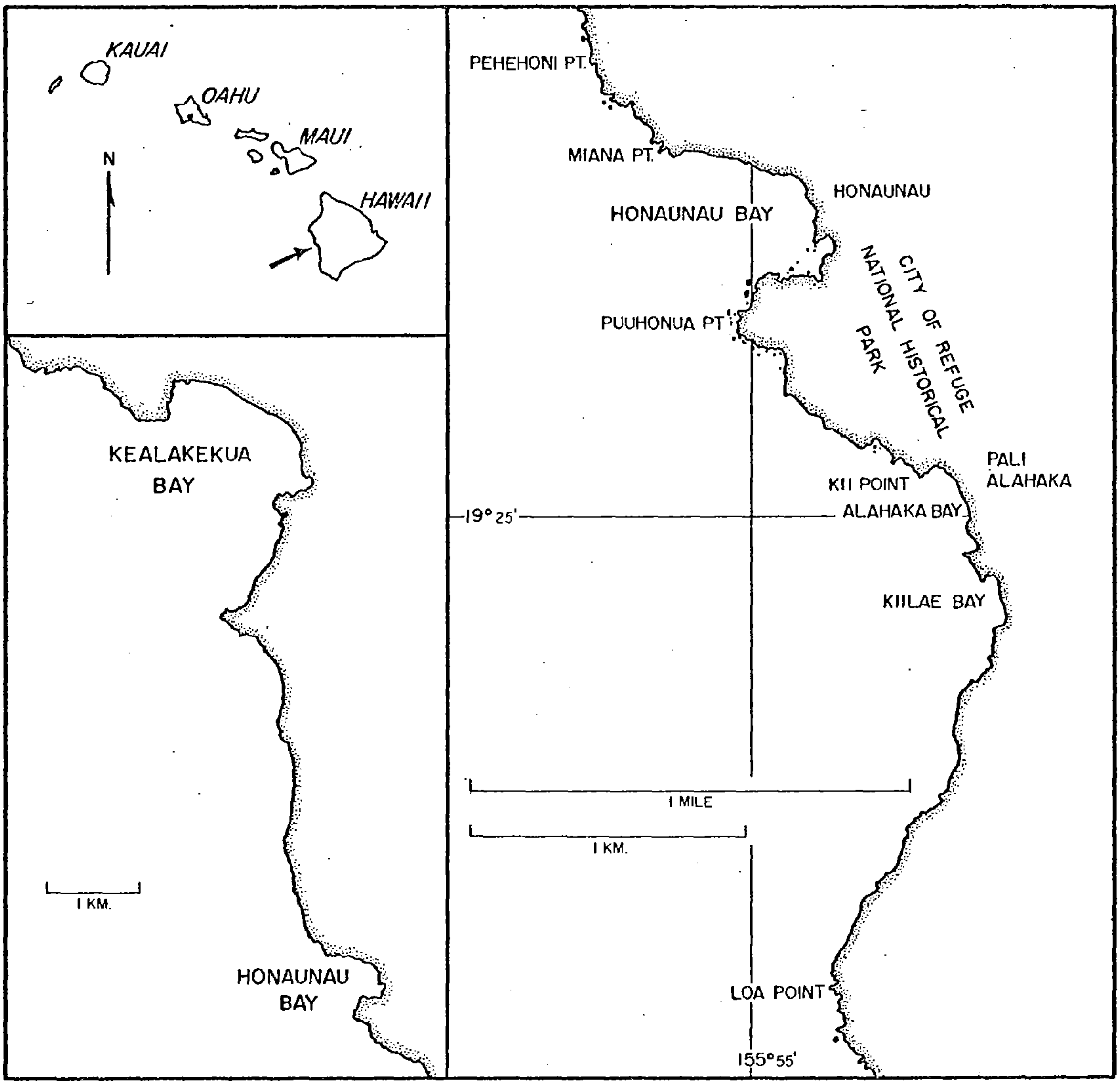

FIGURE 1. Outline of Honaunau Bay and environs indicating its position in the Hawaiian chain.

Dr. Stephen L. Lau, Water Resources Research Center, University of Hawaii, for similar assistance with the chemical analyses.

Of the various graduate assistance involved in this study, Mr. Michael Noonan aided in gathering much of the field data and Messrs, G. Kraft and M. Littler, the algal taxonomy. Persons specifically aiding Mr. Henry Sakuda (and sometimes Mr. Kenji Ego) in the Fish and Game surveys include Messrs. T. Fujimura, R. Kanayama, P. Kawamoto, E. Onizuka and C. Vares.

To the end that Honaunau Bay and the City of Refuge N. H. P. is developed to the maximum benefit of the people of Hawaii, the coordinator wishes to express his appreciation to the above and to the farsightedness of the Park Service officials who encouraged the making of this study.

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Chapter 1

BACKGROUND

A. The City of Refuge National Historical Park.

The City of Refuge N. H. P. (Fig. 1) was authorized by an act of Congress in 1955 and, after land acquisition, resident administration and establishment took place in 1961. It is situated near the middle of the Kona Coast on the island of Hawaii, and covers an area of 180 acres including about one mile of shoreline.

The old village of Honaunau is just north of the park, and the only portion of Honaunau Bay under protection, *i.e.*, within park boundaries, is land to the mean high tide mark surrounding the south third of the bay. Unlike most accessible areas in Hawaii, the Honaunau setting is, except for introduced weedy vegetation, largely unchanged since the arrival of Captian Cook in the 1700's.

Few places in Hawaii are of greater historical significance than here. The City of Refuge, or more properly, the Place of Refuge at Honaunau, is the ancestral home of Kamehameha the Great, the most famous member of the Hawaiian dynasties. The most sacred temple of ancient Hawaii is Hale-o-Keawe, the principal re-created attraction at the park. Keawe is traditionally regarded as Kamehameha's great-grandfather. He died in 1610 and his remains constituted the most important deified contents of the temple.

Kamehameha the Great was the first monarch to unite the Hawaiian Islands into a single kingdom. He began his successful conquest in 1782 from Honaunau, the traditional seat of the Kingdom of Kona. Shortly after the death of Captain Cook the seat of power shifted to nearby Kailua, and still later to Honolulu. Hence until early into the advent of white man, Honaunau was the religious, cultural and political center of Hawaii. More specifically this period lasted from the reign of Keawe, in the late sixteenth century, to the rise of Kamehameha the Great, in the late eighteenth century.

The actual City of Refuge lies on a 20-acre lava shelf on the south edge of Honaunau Bay. It and the immediate environs encompass a complex of ruins representing almost all phases of ancient Hawaiian culture. The refuge is enclosed within a massive stone wall, the Great Wall, built over 550 years ago. Nearby is the thatched temple or mausoleum, Hale-o-Keawe, and a place of worship, Alealea Heiau. The wall and heiau have been restored, and the temple reconstructed, by the National Park Service.

The refuge was established as a sanctuary for non-combatants and defeated soldiers in time of war, for criminals and for taboo breakers. The function of the temple was in granting spiritual protection and safety to such persons. Tradition does not tell when this refuge at Honaunau first started, but it is believed to have been in operation before 1492. Concepts of refuge were part of the Polynesian culture, and it is probable the Chiefs of Kona established a refuge custom at Honaunau rather early in the history of Hawaii.

B. Climate.

The Kona side of the island of Hawaii is almost entirely cut off from the northeast trade winds that blow against the island most of the year. Except for a brief more stormy period from December through February, the climate is pleasantly and uniformly moderate, with breezes of the onshore-offshore variety.

Kona mornings are usually clear. In the early hours cool breezes blow onshore and clouds form at 2,000 feet, causing precipitation at higher elevations. At eventide the winds cease and clouds disappear. Cool night air flows down the mountain slopes and across the coastal area toward the sea.

There is little variation in temperature (Fig. 2) from month to month. The average annual maximum is 88^{o} and the minimum, 65^{o}. The day-night difference is 20^{o}. In the summer there are occasional uncomfortable warm days when humidity is high and air movement is minimal. Rainfall near the coast (Fig. 3) is low, but remains rather uniform at about two inches per month throughout the year. It is highest in June, lowest in December. The annual average is 20 inches. The maximum rate of fall is an inch an hour, but prolonged showers are unusual. The construction season is year-round.

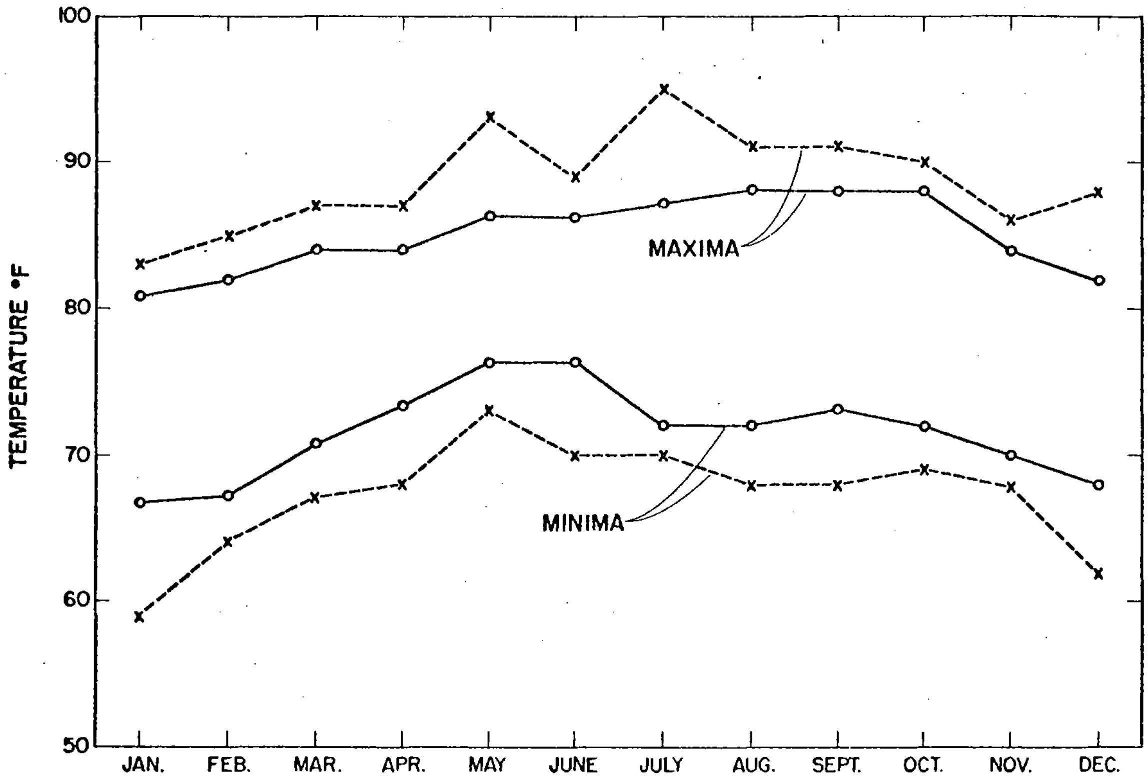

FIGURE 2. Temperature ranges at the City of Refuge N. H. P. from July through December, 1967, and January through June, 1968.

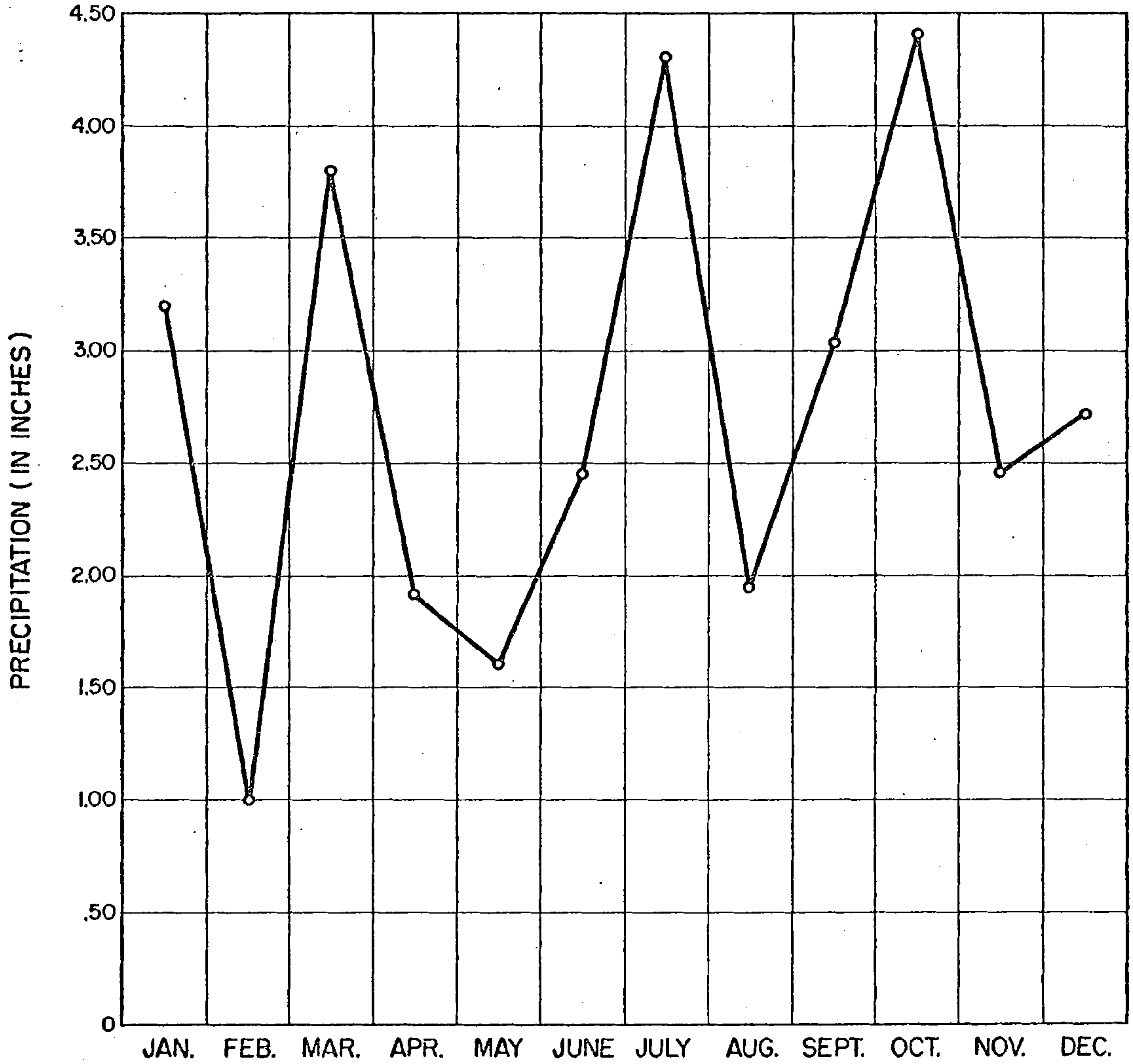

FIGURE 3. Monthly precipitation at the City of Refuge N. H. P. during 1967.

Storms move through the area more frequently from December through February bringing high winds and severe rains from the west. These are termed kona storms, and during such periods high seas and winds create conditions sufficiently hazardous to justify closing the park shoreline to visitors.

Tsunamis (tidal waves) occur infrequently on the Kona Coast. There were three major tidal waves in the 1800's. Since much of the park is below the 50 foot elevation, a special tsunami warning system has been installed by the park in cooperation with the County Civil Defense apparatus.

C. Exploitation of the Habitat.

The awesome magnitude of the current tourist boom is indicated in Table 1.

TABLE 1. Annual number of visitors to the City of Refuge N. H. P. since its establishment in 1961.

Year	Annual number of visitors
1962	37,798
1963	52,198
1964	38,664
1965	165,030
1966	209,785
1967	209,245
1968	250,700
1969 (estimated)	223,000

Besides visitors by land, four tour vessels presently service the area from Kailua-Kona. The Jeannie Marie III and Jeannie Marie IV, with capacities of 90 persons each, schedule once daily cruises in winter, twice daily in summer, to Captain Cook's Monument in Keakalekua Bay, two miles north of the City of Refuge. They stay at the monument and do not visit Honaunau Bay. The two other vessels, Captain Cook IV and Kaimanu, each have capacities of 180 persons. They make daily trips year round to Kealakekua Bay and Honaunau Bay, but do not stop during the cruise.

In a recent study of Kealakekua Bay, the area around Captain Cook's Monument was found to be littered with trash. Some of the bottom is littered with coral dead and broken off by collectors and dragging anchors. Due to complaints over these conditions, the Captain Cook IV in January 1969 discontinued its traditional stopover at the monument for swimming and glass-bottom boat touring.

The park extends along the ocean shore at the mean high tide mark from the south third of Honaunau Bay through Alahaka Bay and part of Kiilae Bay. Both the central and north shorelines of Honaunau Bay lie outside the park, and in terms of scenic protection, preservation and archaeological importance this is most unfortunate. While touring in 1823 Reverend William Ellis estimated Honaunau was a village of 147 buildings, and fully a third of these most likely stood along the north shore. One has only to visit nearby Keauhou or Kailua Bays to see the results of recent and intense pollution of unprotected regions.

Several suggestions have been offered to help preserve the Honanunau Bay and setting. All would bring the bay more fully under control of the National Park Service. One suggestion is purchase of the entire bay periphery, particularly the north shore. Another involves purchasing instead a scenic easement of the land. A third suggestion is to make a natural preserve of all waters inshore of a line drawn from Miana Point to Loa Point (Fig. 1), a distance slightly less than two miles. Establishing such a preserve would vastly aid in maintaining the beauty and natural importance of this wilderness area for the enrichment of future generations, and conversely, there is no reason at all to expect that this bay will not become murky and more polluted in the near future without protective measures. The implications of the present Kona Coast population influx cannot be minimized. The entire coast is undergoing development at an astonishing rate, and terming the region a wilderness area is in itself already anachronistic and fanciful.

At the present time, exploitation of the marine areas at Honaunau ranges from minimal to detrimental. It principally included trash dumping and the taking of coral, fish, mollusks and crustacea.

A dozen outrigger fishing canoes are stored on the beach of Kapuwa'i cove. Opelu (Decapterus pinnulatus), a mackerel-like fish, is caught offshore by line at night. Park records state there are four thousand instances of this type of fishing per year, but during the present survey, no more than five boats were out on any one night.

Pole fishing along the shore is popular, as is also net fishing. Opelu schools are netted by day from outriggers, and along the shore one may observe throw netting in the traditional Hawaiian manner. Surrounding nets are also commonly used in Honaunau Bay. In this case a net is stretched across a section of the bay and swimmers chase the fish toward it. As the fish approach the net the ends are brought together, surrounding the fish. Forty fish were observed by one researcher to be caught off Hale-o-Keawe by seven men in one 20-minute stretching of the net. Fish are also speared both by divers and, in the evening, from the shoreline. At the time of the survey, however, relatively little spearfishing was observed.

As noted in Chapter 12, fish are very abundant here contrasted with populated areas in Hawaii. However, in a casual SCUBA survey of the coastline from Honaunau south past Loa Point, it was observed that fish (and lobster) populations dramatically increased as one approached totally uninhabited areas. Hence, we presently have strong human foraging factors even here in seemingly remote Honaunau, and with adequate protective measures the populations may very well be expected to increase. As an aside, land has been cleared for numerous subdivisions south of Loa Point, and it is extremely doubtful that even minimum protective measures will be taken to safeguard the rich shoreline biota in this area.

Various mollusks, principally opihis (Cellana spp.) and pipipis (Nerita spp.); and crustacea, the ama crab (Grapsus grapsus), are popularly collected in tidepools for human consumption. All manner of sealife is taken from tidepools and reef areas as fishing bait.

Lobsters are scant here, found only by knowledgeable divers. Nevertheless, they are hunted and eaten. Seven-eleven crabs (*Carpilius maculatus* L.) are caught off Miana Point. Kona crabs (*Ranina serrata*) are trapped in sandy areas at depths of 200 to 300 feet, principally in front of Alahaka Bay. In times past it is reported the Kona crab population has been severely decimated in this manner.

Skin divers collect all manner of shells, and during the survey a team of divers from a local curio shop collected young, budding coral heads from Honaunau Bay for sale to tourists.

A blight from littering is an artificial reef constructed and left in Honaunau Bay during the filming several years ago of the movie, *Ice Station Zebra*. There is also an abundance of beer bottles and trash in shallow water fronting the Japanese Young Men's pavillion near the northeast reach of the bay.

D. Survey aids.

The various maps and profiles included in this report were taken from Coast and Geodetic Survey Charts, U.S. Geological Survey charts, Army Map Service Maps and from aerial photographs. The basic maps and charts are available from a variety of sources, including Trans-Pacific Instrument Company, 1406 Colburn, Honolulu, and the U. S. Geological Survey, 345 Middlefield Road, Menlo Park, California. Used most frequently in this survey were USGS map 5106 (1959) and USC&GS chart 4123 (1967).

Aerial photographs are particularly useful in studies such as the present one. Most of the commerical Honolulu aerial photography concerns (listed under *Photographers-Aerial* in the yellow pages) have sets or access to sets of these photographs, or they may be purchased from the Aerial Photography Division of the Agricultural Stabilization and Conservation Service, U. S. D. A., 2505 Parley's Way, Salt Lake City, Utah. Aerial photographs of various specifications are also filed by the Land Study Bureau, University of Hawaii, and by the Earth Sciences Department, Hawaii Institute of Geophysics, University of Hawaii.

The City of Refuge N. H. P. has extensively chronologed the history of the region in photographs, including some early aerial views.

The prints are mounted, numbered and described, and reproductions are available through their courtesy.

Chapter 2

GEOLOGY

The island of Hawaii is located at the southeastern end of the Hawaiian chain, the youngest and most lofty of the group. The City of Refuge N. H. P. lies on the western slope of Mauna Loa (13,680), near the middle of the Kona Coast, approximately 21 miles due west of the summit and six miles south of Hualalai Volcano. The general slope of Mauna Loa is not severe. It drops about 500 feet per mile, a gradient of 12.5 per cent or 7.2 degrees. The slope continues beneath the sea to the 2,000 fathom line 14 nautical miles offshore, at a gradient of 14.1 per cent or about eight degrees. Below this depth the slope flattens out in a westerly direction.

The principal physical feature in the City of Refuge N. H. P. is small and attractive Honaunau Bay. It lies 2.5 miles south of Kealakekua Bay where Captain Cook was killed, and a little north of the old village of Hookena where Robert Louis Stevenson did some of his writing.

Most of the park lies below the 30 foot contour. The shoreline is flat. The slope of the land rises gradually to a fault escarpment, Pali Alahaka, which is 120 feet high at its highest point within the park. There is local quake activity connected with this fault. The last serious quake occured in 1951, razing many buildings in the vicinity of the park.

The majority of the part terrain is bare pahoehoe lava. It is exceedingly rough with billows, pockets, cracks and loose rocks. The north end of the Place Grounds (Fig. 4) is grassy and the two nearby coves are sandy. These are the only sandy areas along the park shoreline, consisting of an attractive mixture of coarse and fine black, white, brown and grey particles. The major sand constituents are basalt, obsidian, olivine and calcium carbonate particles.

There is very little soil within the park. The soil present consists of only accumulations of weathered lava bits, material from the sea and vegetal debris in pockets and depressions in the pahoehoe

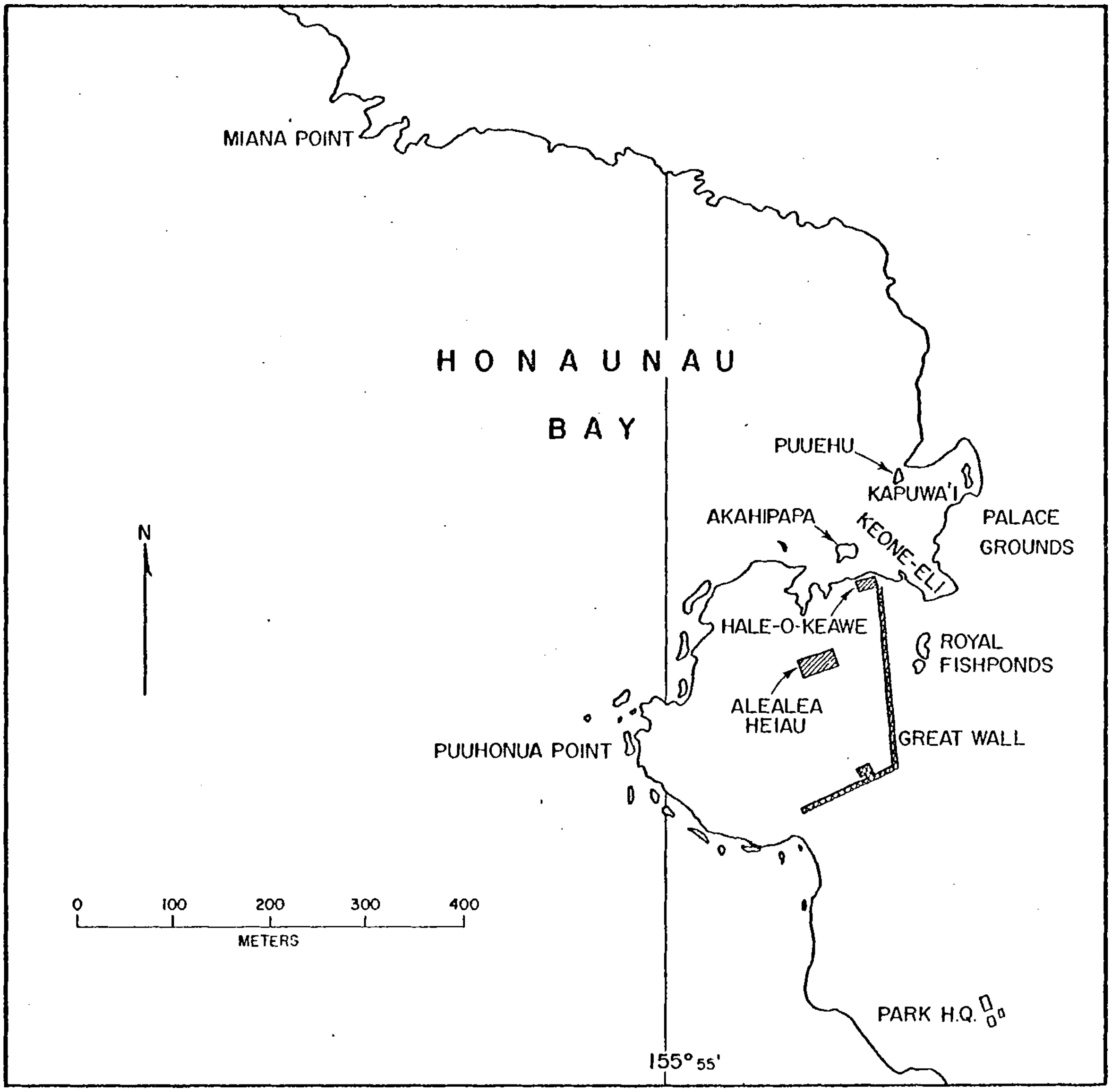

FIGURE 4. Profile of Honaunau Bay with the place names used in this survey.

Pu'uhonua o Honaunau N H P
Library

lava terrain.

The Honaunau coastal plain on which the City of Refuge is situated was formed by prehistoric lava flows from Mauna Loa, followed by a coastal fault subsidence which continues (Apple and Macdonald, 1966) today at a settling rate of one foot per hundred years. Mauna Loa is still active. It last erupted in 1950 at which time three lava flows descended the western slope of the mountain and entered the ocean. The northernmost of the flows reached the sea seven miles south of Honaunau Bay.

Above Honaunau the slope of Mauna Loa consists of innumerable thin flows of basalt lava. North of the northernmost flow of 1950 all of the lavas are prehistoric, though they are of Recent geologic age. Both pahoehoe and aa types are present. The aa flows have rough clinkery surfaces, and often clinkery bottoms, with relatively dense massive central portions. The pahoehoe flows have smooth, billowy or wrinkled ("ropy") surfaces. They commonly contain lave tubes, which are the open pipe-like channelways through which liquid lava moved feeding the front of the flow when it was active. At the end of the eruption a decrease in the supply commonly allows the liquid to drain out of the channelways, leaving the pipe-like tube open. The lava flows formed layers generally between five and 20 feet thick which slope seaward over most of the western flank of the volcano at an angle of about 7.5 degrees from the horizontal.

Near sea level the western slope of Mauna Loa is broken by several faults on which the portion of the volcano seaward of the fault has moved downward relative to that on the landward side. The faults are not single fractures, but groups of subparallel fractures known as fault systems. Two systems affect the area near Honaunau Bay. The Kaholo fault system lies close to the shoreline from a point just south of Honaunau southward for 15 miles or more, to the vicinity of Milolii. This fault system has produced a seaward-facing cliff (fault scarp) that lies one-fourth to one-half mile inland from the shoreline. It has been mantled by lava flows from the upper slope of Mauna Loa. The cascades and draperies of lava along the buried fault scarp are well displayed just south of the ancient City of Refuge at Honaunau.

The City of Refuge itself lies on a coastal flat built by a pahoehoe lava flow that spread out below the scarp.

The faults of the Kealakekua system extend southeastward from the head of the bay for about three miles, then bend southward and disappear beneath younger lava flows, although the abnormally steep slope indicates that they probably continue southward beneath the lava cover for at least four miles more. Lava flows moving downslope over the fault scarp have spread out beyond it forming the broad gently-sloping apron that borders the coast between Kealakekua Bay and Honaunau. The Keei Battlefield is located on this flat.

The only historic eruption within the area took place beneath the ocean in 1877. At that time (February 24, 1877) steam and fragments of lave rose along a west-northwest-trending fissure in Kealakekua Bay and for a mile or so farther out to sea. A continuation of the crack is said (Whitney, 1877) to have extended inland nearly 3 miles, and clouds of steam and smoke issued from the fissure either in that area or farther up the mountainside (Westervelt, 1916). The eruption was preceded by a severe earthquake.

Chapter 3

CURRENTS

Measurements of the current system in Honaunau Bay were carried out on 6-III-69. On this date the tide reached flood stage at 0500, receded 1.5 feet to an ebb at 1130, then rose 1.6 feet to a second flood at 1800 hours. Hence, the tide was falling during the morning and rising during the afternoon in a 13-hour cycle.

Only movement in the upper meter of water was measured. The wind was absent in the morning hours and slight from the east during the afternoon. Wind resistance was not determined, but was considered of minor importance due to its absence and to the construction of the current devices.

Time and equipment did not permit more sophisticated research in "flushing times" of the water mass, determination of thermoclines and so forth. However, in a study of nearby Kealakekua Bay in October 1968, no thermocline was detected to a depth of 400 feet. In the present study, emphasis was given to overall movement of the upper meter of water, and to determing shifting patterns in regions where brackish water is concentrated.

Seven current drogues of a modified drogue-buoy design were constructed and tested in the field. They consisted of partially submerged aluminum floats supporting a wooden "X" frame. The frame was hung at a depth of one meter, held vertical by basalt weights, and was made of four 10-by-10-inch-square boards nailed to a center post at right angles to one another.

The current to one mile outside the bay was southerly and strong (500 m/hr). Flagline fishing boats beyond a mile offshore were noted to be drifting north. According to local fisherman, the current to a mile out generally flows northwestward from April to October at a slower pace than in winter months when the direction is generally southerly. In November 1968 the currents in a nearby Kealakekua Bay were measured, and on that occasion the offshore flow was southerly and strong.

At the flood (Fig. 5) the upper meter of water flushes directly outward (west). Then, as the tide recedes (Fig. 6), the rate quickens and the direction shifts southwest. The rate again slows approaching the ebb (Fig. 7), and the direction of flow at this time is southerly, similar to that beyond the bay. Along the south shore at this time movement is minimal and westward, and the drogues tended to beach. The rate near ebb tide along the eastern shore is 50 m/hr, which differs from beyond the bay by one order of magnitude. As the tide rises the current quickens and several circular patterns (Fig. 8) are instituted. Movement is now northerly at the head of the bay.

The topography of a bay affects its current system. In the case of Honaunau Bay, a very deep trench extends outward along the southfacing shore while the majority of the bay is relatively flat. During a rising tide the current buoys float north to the trench and then follow it westward to sea. They converge over the trench and are then carried out at a quickened rate. By contrast, during a falling tide the buoys are pulled out to sea before drifting this far north, and those placed over the trench float southwestward across it without noticeable influence.

The only major brackish areas in Honaunau Bay not exposed, as measured by the rate that drogues floated to sea, were Stations 12 and 13 (Fig. 9), and to a lesser extent Stations 15 and 16 along the south shore. However, the volume of percolation from these two latter stations is not great. The brackish lenses from Stations 12 and 13 converge in a common channel off Puuehu rock leading into the bay proper. Movement of the water from this region was carefully studied.

Flushing here is most rapid during a falling tide. One current buoy placed midway between Puuehu rock and the sandy shore of Keone-eli (Sta. 13) travelled over 200 m/hr at that time, north then west. Movement during a rising tide is similar except the buoys are pulled northward for a greater distance, until over the trench, and are then swept westward to sea. Toward the ebb, when movement slows to 50 m/hr, the buoys placed inside Puuehu rock immediately beach. Outside Puuehu rock they move slowly westward along the southern shore of the bay.

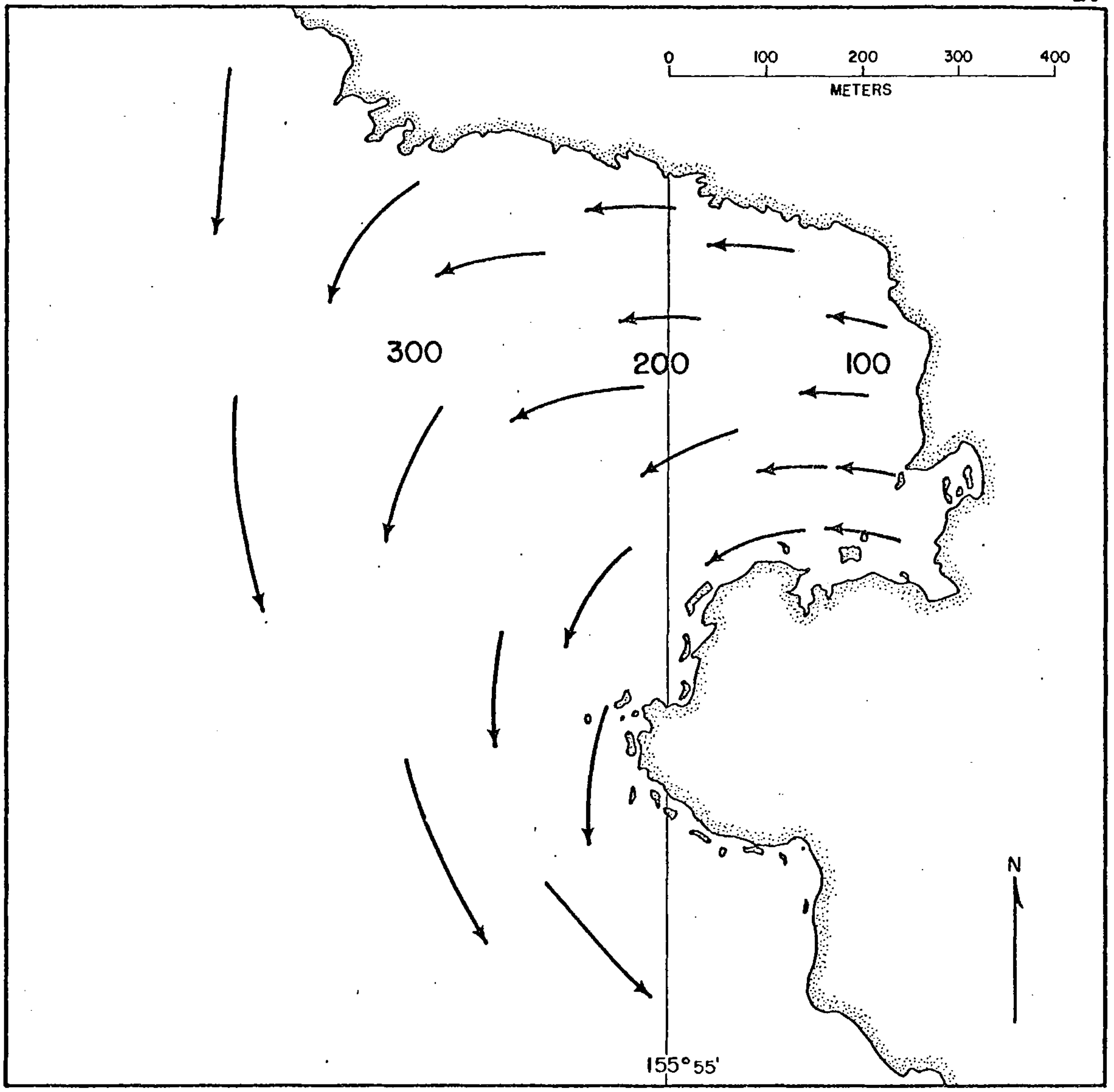

FIGURE 5. Movement of the upper meter of water at flood tide. The numbers refer to meters per hour as measured in different parts of the bay.

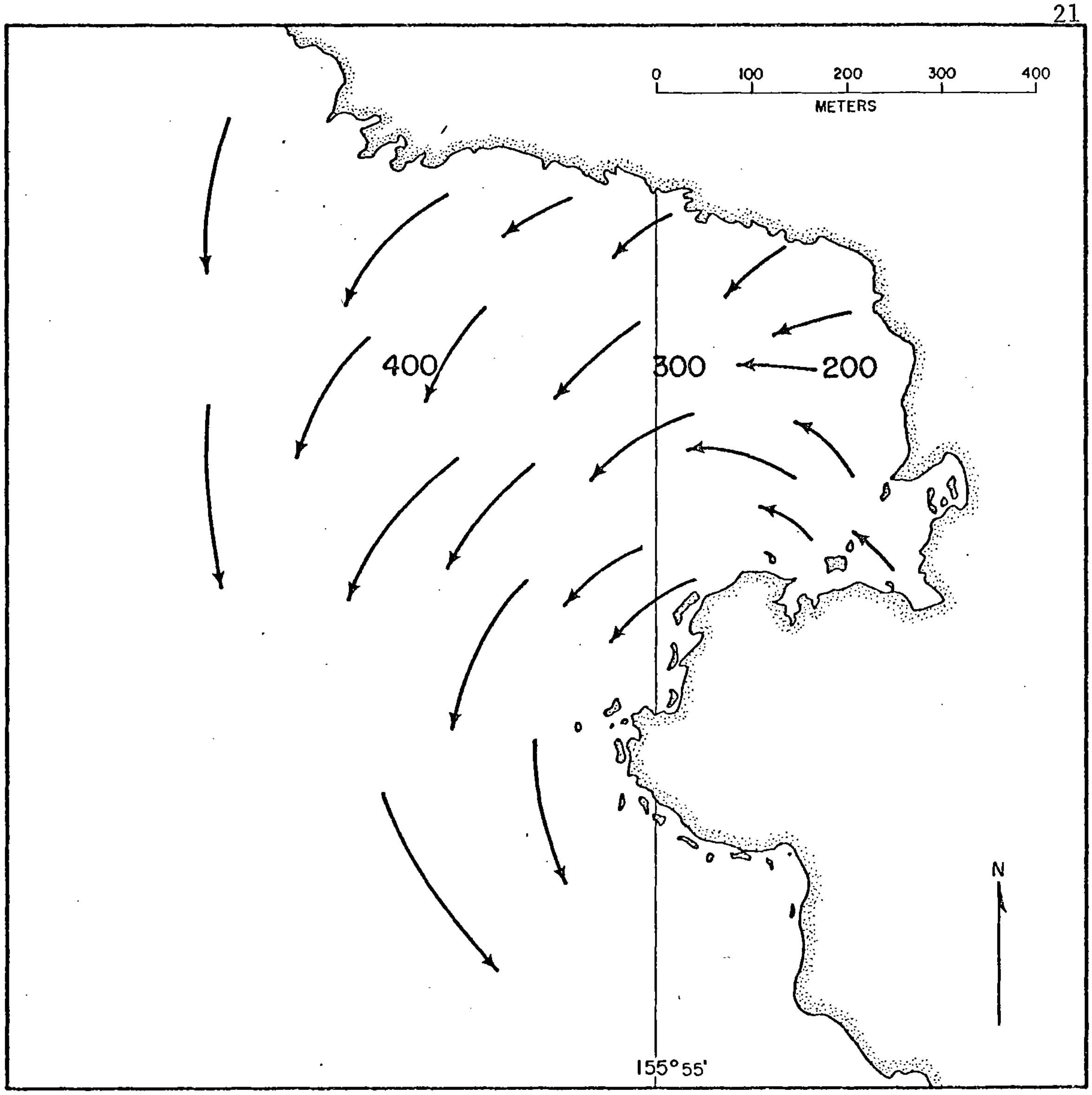

FIGURE 6. Movement of the upper meter of water during a falling tide. The numbers refer to meters per hour as measured in different parts of the bay.

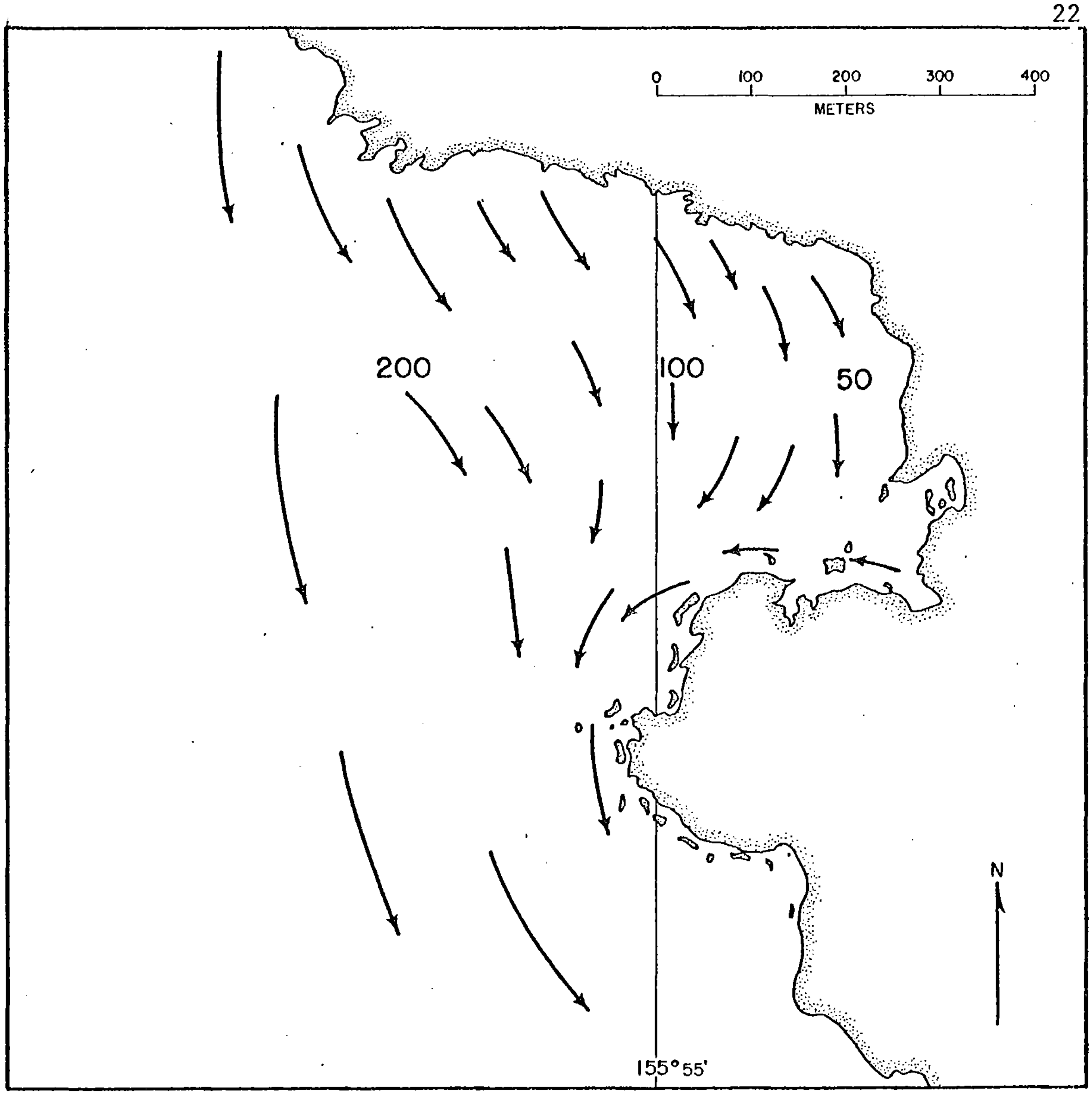

FIGURE 7. Movement of the upper meter of water at ebb tide. The numbers refer to meters per hour as measured in different parts of the bay.

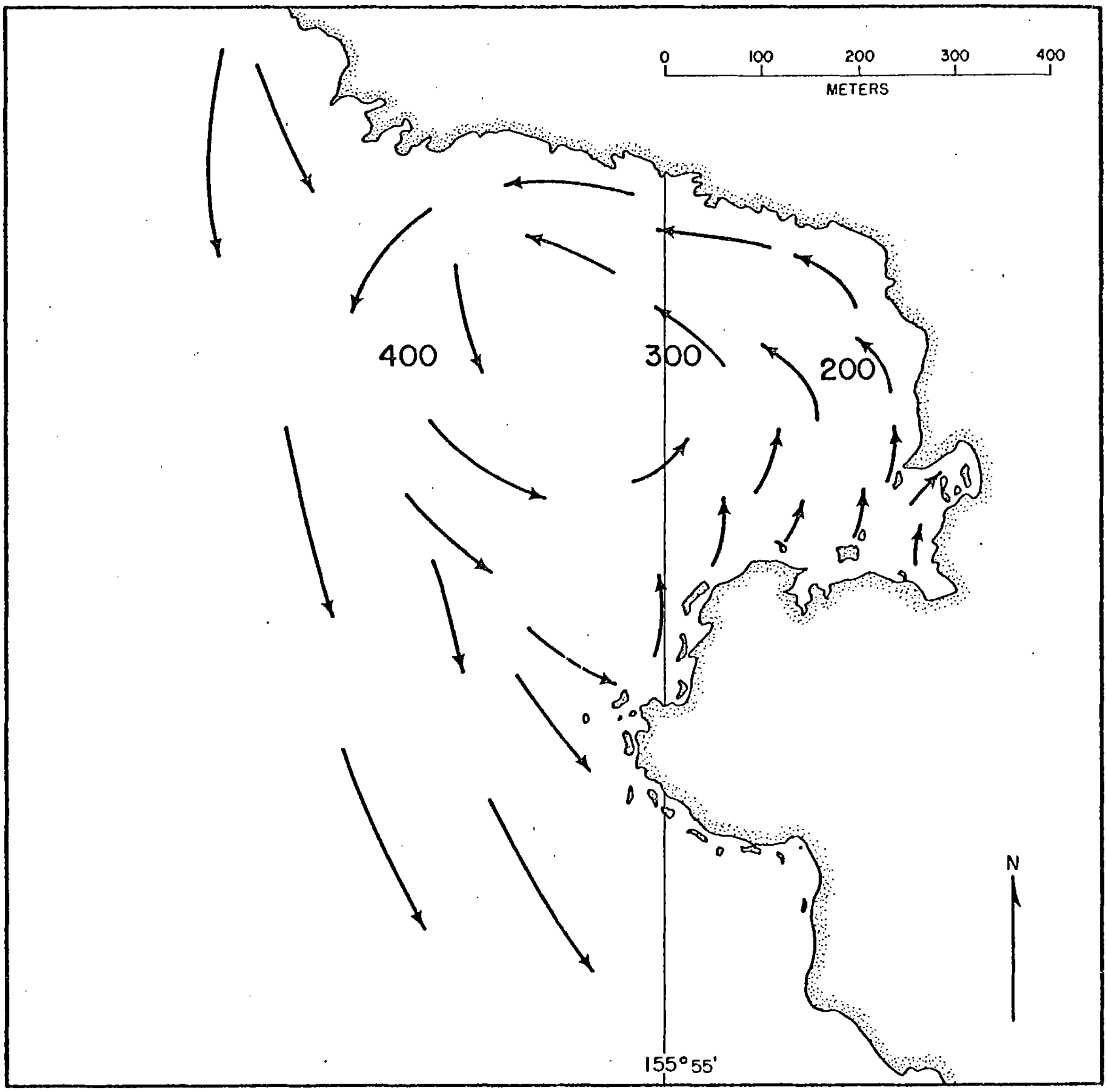

FIGURE 8. Movement of the upper meter of water during a rising tide. The numbers refer to meters per hour as measured in different parts of the bay.

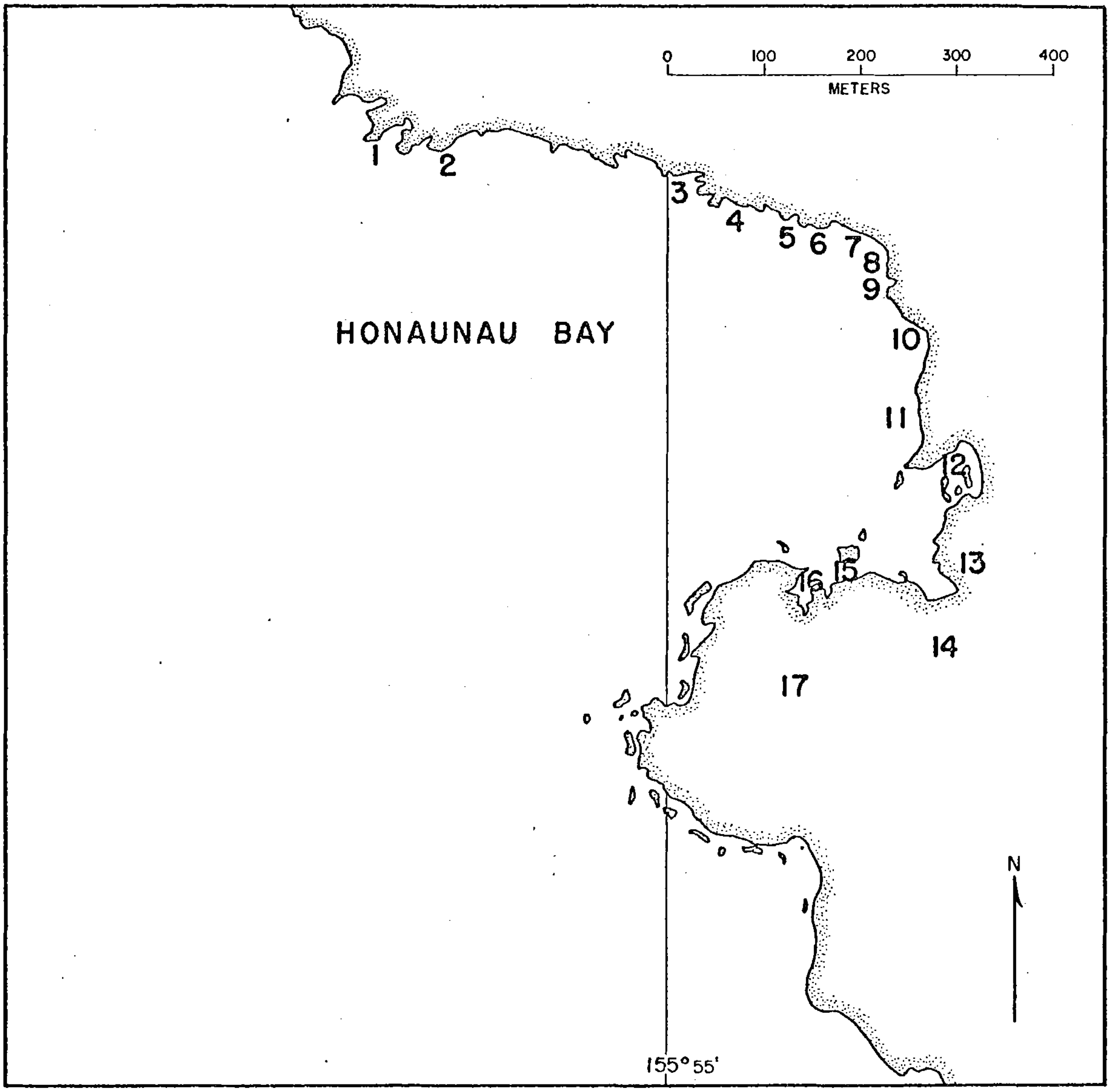

FIGURE 9. Areas of brackish water concentration.

The present current study points up the exposed nature of Honaunau Bay rather than demonstrating protected areas. Whereas the inlet Keone-eli appears quite sheltered to the eye, during both falling and rising tides the water mass shifted from this area into the bay proper at rates from 100 to 200 m/hr. The nearby deep trench extending to almost the head of the bay is instrumental in this flushing pattern.

In a recent study of Kealakekua Bay, employing the same equipment and researcher, sheltering was dramatically emphasized. Movement along the periphery of this much larger bay averaged only 50 m/hr, and furthermore the buoys tended to remain within the confines of the bay during the entire tide cycle. Coincidentally, the incidence of beaching was much higher in Kealakekua Bay.

Chapter 4

BRACKISH WATERS

"Brackish water" in this chapter refers specifically to percolation into the bay of water from the surrounding land mass.

The shoreline from Miana Point to Loa Point, two miles south of Honaunau Bay, was surveyed for such brackish water. Rainfall was absent during and several weeks prior to the survey, and most of the sampling was done near ebb tide when the freshwater lenses, or layers of brackish water overlaying the sea water, are at a maximum. No streams empty into the area studied.

The entire periphery of Honaunau Bay and the shoreline south to Alahaka Bay were surveyed for brackish water on foot and by boat. Testing was of salinity as shown on a hand refractometer, lowered temperature and refractive turbulence in the area as noted with a view box or face mask. A total of 19 discrete brackish stations (Fig. 9) were established, 17 of which are within Honaunau Bay.

The majority of stations was sampled on several occasions, and with results (Table 2) often dissimilar due to tide height differences. Surface and depth samples were taken from a variety of points near each station. Tests were run to measure salinity, temperature, total phosphate content, total nitrate content, coliform count and fecal coliform count. The nitrate and phosphate samples were immediately packed in dry ice, and the bacteria samples stored at 40° C and immediately hand-carried by plane to the Department of Health in Honolulu for analysis.

The volume of freshwater percolating into Honaunau Bay is very considerable and is at a maximum at Stations 12 and 13, located near the head of the bay. The brackish lenses of these two stations converge at Puuehu rock and emerge into the bay proper as a single lens. This is the only area in the bay where a brackish lens is detectable by boat, and it is further augmented by numerous points of freshwater seepage west of Station 13 to Hale-o-Keawe, collectively referred to as Station 15.

TABLE 2 Brackish water characteristics.

Station no.	Time	Tide	Description	Salinity (ppt)	Mpn coliform per 100 ml	Mpn fecal coliform per 100 ml	µg/l nitrate	µg/l nitrite	µg/l phosphate	µg/l ammonia
1	2-III-69	0.0 ebb	shoreline surf	29.0						
2	2-III-69	0.0 ebb	tidepool surface	7.0						
3	2-III-69	0.0 ebb	shoreline surf	32.0						
4	2-III-69	0.0 ebb	shoreline surf	24.0						
5	2-III-69	0.0 ebb	shoreline surf	28.0						
6	2-III-69	0.0 ebb	shoreline surf	25.0						
7	2-III-69	+0.1 rising	shoreline surf	26.0						
8	2-III-69	+0.1 rising	shoreline surf	31.0						

TABLE 2 (continued)

Station no.	Time	Tide	Description	Salinity (ppt)	Mpn coliform per 100 ml	Mpn fecal coliform per 100 ml	µg/1 nitrate	µg/1 nitrite	µg/1 phosphate	µg/1 ammonia
9	2-III-69	+0.1 rising	shoreline surf	31.0						
			30 m offshore, surface	32.0						
10	2-III-69	+0.1 rising	shoreline surf	25.0						
			shore, 3 m south	29.0						
	9-III-69	+1.8 flood	shoreline surf	34.0						
			20 m offshore, surface	34.5						
	11-III-69	+0.2 falling	shoreline surf	32.5	9	4	74.0	0.6	19.3	negligible
11	2-III-69	+0.1 rising	shore & offshore: mean reading, high, low	31.0 33.5 29.0						

TABLE 2 (continued)

Station no.	Time	Tide	Description	Salinity (ppt)	Mpn coliform per 100 ml	Mpn fecal coliform per 100 ml	µg/l nitrate	µg/l nitrite	µg/l phosphate	µg/l ammonia
	11-III-69	+0.2 falling	shoreline surf	33.0	93	negative	18.9	0.5	8.9	negligible
12	20-X-68	+1.0 falling	shore, surface	10.0						
			shore, 30 m north	34.0						
			shore, 10 m south	24.0						
	4-III-69	+0.1 rising	shore, surface	3.0						
			30 m offshore, surface	23.0						
			30 m offshore, bottom, 1 m depth	27.0						
	9-III-69	+1.8 flood	shore, surface	25.0						
			30 m offshore, surface	29.0						

TABLE 2 (continued)

Station no.	Time	Tide	Description	Salinity (ppt)	Mpn coliform per 100 ml	Mpn fecal coliform per 100 ml	µg/l nitrate	µg/l nitrite	µg/l phosphate	µg/l ammonia
			30 m offshore, bottom, 1 m depth	32.0						
	11-III-69	+0.2 falling	shore, surface	5.5	93	9	727.22	0.6	141.1	negligible
			30 m offshore, surface	20.0	93	15	193.48	1.5	47.8	negligible
	20-X-68	+1.0 falling	shore, surface	10.0						
			shore, 15 m north	30.0						
	4-III-69	+0.1 rising	shore, surface	17.0						
			20 m offshore, surface	28.0						
13	9-III-69	+1.8 flood	shore, surface	31.0						
			20 m offshore, surface	32.0						

TABLE 2 (continued)

Station no.	Time	Tide	Description	Salinity (ppt)	Mpn coliform per 100 ml	Mpn fecal coliform per 100 ml	µg/l nitrate	µg/l nitrite	µg/l phosphate	µg/l ammonia
	11-III-69	+0.2 falling	shore, surface	21.5	23	4	227.5	2.9	45.5	negligible
			20 m offshore, surface	24.5	1100	460	146.7	1.5	38.7	2.0
			20 m offshore, bottom, 1 m depth	26.5	240	23	129.7	1.4	47.1	6.0
14	9-III-69	+1.8 flood	makai end mauka end	9.0 7.0						
	11-III-69	+0.2 falling	surface, 1/4 m depth	8.0	93	43	232.2	3.2	65.4	11.7
15	1-III-69	+0.2 falling	shoreline surf	24.0						
	9-III-69	+1.8 flood	shoreline surf	34.0						
	11-III-69	+0.2 falling	shoreline surf (replicated)	31.0	9 9	9 9	36.4	0.7	16.5	5.1

TABLE 2 (continued)

Station no.	Time	Tide	Description	Salinity (ppt)	Mpn coliform per 100 ml	Mpn fecal coliform per 100 ml	µg/l nitrate	µg/l nitrite	µg/l phosphate	µg/l ammonia
16	4-III-69	+0.1 rising	lowest reading, surface	32.0						
			inlet mouth, surface	34.0						
17	2-III-69	0.0 ebb	surface: mean reading, low, seaward end	15.0 12.0 20.0						
	11-III-69	+0.2 falling	near heiau, surface	31.0	9	9	97.1	0.8	20.9	11.9
			draining into surf	34.5	negative	negative	negative	4.8	12.7	negligible
			shoreline surf, 20 m west	34.5	15	3	2.6	0.1	4.3	negligible
18	29-X-68	+2.0 flood	mean reading, bay surface	34.0						
			mean reading, 1 m depth	34.5						

TABLE 2 (continued)

Station no.	Time	Tide	Description	Salinity (ppt)	Mpn coliform per 100 ml	Mpn fecal coliform per 100 ml	µg/l nitrate	µg/l nitrite	µg/l phosphate	µg/l ammonia
	8-III-69	0.0 ebb	bay surface:							
			mean reading	34.0						
			low	33.0						
			high	34.5						
19	28-X-68	+1.7 falling	shore, surface	30.0						
			50 m offshore, surface	33.0						
			100 m offshore, surface	34.0						

The north shore is fringed by a 4-m high basalt bluff which becomes lower and even dips into the sea at Miana Point. This coast borders a wide and deep trench and is considerably more exposed than the south shore which is flat and fringed by a reef. The volume of freshwater percolation is greater into the northern than the southern shore.

A researcher swam the length of the surf-lashed north shore collecting water samples wherever he noted a lowering in water temperature. In this manner 11 distinct points of freshwater entry were established.

No fresh water at all was detected between Honaunau Bay and Alahaka Bay. The shore is a flat, exposed lava shelf lashed often by treacherous surf. Abundant surf and offshore samples were taken here as well as in Alahaka Bay itself where it is equally dangerous to swim near shore. The shoreline from Alahaka Bay south to Loa Point was surveyed exclusively by boat.

The phosphate, nitrate, coliform and fecal coliform levels at brackish water stations in Honaunau Bay were compared with the State of Hawaii public health standards regarding water quality (Public Health Regulations, Chapter 37-A). The entire bay meets standards for "AA Water" save for Keone-eli cove (Sta.13) which meets the standards for only "B Water".

"AA Water" is pristine, characteristic of a wilderness region. "A Water" is less so, but is regarded as completely suitable for swimming and recreational use. "B Water", on the other hand, is thought too contaminated for swimming, and suited instead for such use as a small boat harbor.

In general, sufficient replicates were not possible to make more than preliminary conclusions about the nature and constituents of the brackish water in Honaunau Bay. Further it might be pointed out that it was necessary to do the nitrate, phosphate and bacterial sampling before sunrise, at 0600 hours. It is probable that greater bacterial activity would be noted during the heat of the day.

Overall the waters of Honaunau Bay are sparkling and exceptionally clear. The bottom is visible to 60 feet. A single exception, however, is the region (Sta. 13) off the Palace Grounds. Here the water is strongly discolored with an abundance of suspended matter. There are fewer fish here than elsewhere in the bay, and the substratum is algal rather than coral. Specifics are presented in the chapter discussing algae.

The contamination at Station 13 is from a cesspool situated 34 m from the sandy-beach shoreline. The public restroom it services was erected years ago by the county as previous to 1955 the City of Refuge N. H. P. was a county park. The National Park Service recently erected a visitor's center with additional restrooms. The original plans called for a sewage treatment plant located on the hillside behind the park, but the plan (costed at $60,000) proved inadequate, and a revised estimate ($130,000) was submitted. Meanwhile, as a stopgap measure a second cesspool was constructed 53 m from the shoreline behind the county cesspool. The State had condemned the original cesspool as inadequate to service the burgeoning tourist industry (250,000 visitors in 1968), but has granted a temporary, 2-year approval for the present system. It is thought that in 1971 funding will be available to institute the sewage treatment plant.

Not only is Keone-eli cove contaminated, but this is the most popular bathing area in the entire bay, favored by those wanting to avoid the more exposed, deeper waters of the bay proper. Park records state that several thousand swimmers use this cove annually. As indicated above, this cove does not meet State sanitary water standards for a swimming beach.

Near the cesspools is (Sta. 14) a small pond historically titled the Royal Fishpond. Its condition is an embarrassment to the park personel and tour guides who studiously circumvent it. It is a brackish pond, polluted and with an average depth of one foot. A second regal fishpond in similar condition lies behind it.

A serial listing of brackish-water stations follow.

Station 1. In shoreline surf by Miana Point, 125° magnetic to Hale-o-Keawe.

Station 2. East of the above, 131° to Hale-o-Keawe. This is a shoreline fissure resembling a tidepool. Refractive distortion and lowered temperature due to fresh water were both noted.

Station 3. In shoreline surf, 140° magnetic to Hale-o-Keawe.

Station 4. In shoreline surf, 154° to Hale-o-Keawe.

Station 5. In shoreline surf, 157° to Hale-o-Keawe.

Station 6. In shoreline surf, 162° to Hale-o-Keawe.

Station 7. In shoreline surf, 167° to Hale-o-Keawe.

Station 8. Fronting the Japanese Young Men's pavillion, 171° to Hale-o-Keawe.

Station 9. Fronting a private house, 174° to Hale-o-Keawe.

Station 10. An inlet at the south edge of the row of private houses, 180° to Hale-o-Keawe.

Station 11. This station is not specific. It encompasses the offshore area fronting the lava flat at the head of Honaunau Bay. Refractive turbulence and lowered temperature were noted at several points 10 to 20 m offshore.

Station 12. The beach area known as Kapuwa'i cove where local fishermen store outrigger canoes. The greatest percolation of fresh water into Honaunau Bay was detected at this station. At low tide fresh water streams onto the beach from rock fissures at a rate of five gallons per minute. Dogs quench their thirst here and fishermen use the beach water to wash sea water from their boats.

Station 13. The sandy beach fronting Keone-eli cove. The volume of freshwater percolation into this swimming beach is second only to Station 12, and is augmented by freshwater leaching at points along the entire south shore to Hale-o-Keawe. This station is shallow and landed on all sides save for a narrow entrance into the bay proper. Pollution here is discussed above.

Station 14. Known as the Royal Fishponds. These two brackish and polluted ponds south are (Sta. 13) of the cesspools and are a source of concern to park personnel. The salinity shows no diurnal variation.

Station 15. Fronting Hale-o-Keawe. Freshwater seepage was noted at several points between here and Station 13.

Station 16. An inlet west of Hale-o-Keawe. Percolation is slight and only detectable at low tide.

Station 17. An extensive, shallow tidepool by Alealea Heiau. The fresh water is concentrated at several points, and is visually detectable.

Station 18. Alahaka Bay. Several freshwater "chimneys" were reported by SCUBA divers surveying this area. This is to say, fresh water emerges from fissures in the floor of the bay and rises to the surface as a refractively distorted column.

Station 19. A rocky cove south of where Pali Alahaka enters Alahaka Bay. Fresh water is detectable 50 m from shore during an ebb tide. No further areas of brackish water were detected south to Loa Point.

Chapter 5

UNDERWATER TOPOGRAPHY

1. General description south from Kealakekua Bay to Loa Point.

The shoreline at a distance of 30 to 80 meters from shore was surveyed by boat with the aid of a glass-bottom view box from Palemano Point to Loa Point, south of Honaunau Bay. This survey was not quantitative, but rather its purpose was to check the general pattern and note gross irregularities in the nature of the substrate, flora and fauna; to determine if the bottom conformed in general to other areas more extensively surveyed.

The south side of Palemano Point at a depth of 10 meters is a smooth volcanic shelf with numerous large boulders; no sand; the crust is 60% to 70% exposed. *Pocillopora meandrina* and *Porites pukoensis* (castle *Porites*) are the corals present; going south, no sand observed at all.

Opposite Keomo Point a sample of brownish-colored seaweed matting, 1/2 cm high which covered over 50% of the exposed portions of the boulders was collected in this area at a depth of 10 meters. Similar mattings were abundantly noted on boulders from Palemano Point to Honaunau Bay. Other encrusting seaweeds not scraped off for inspection, but common along this shoreline, consisted of smaller, more isolated patches of blue, green and orange hues. The sample collected was principally *Laurencia*, but included a very rich floral aggregation of green, red, brown and blue-green algae. The specific genera are dealt with in Chapter 7.

Near Kipu Rock the boulders average one meter in diameter and are 80% algae-encrusted, 15% bare and 5% coral-dominated. From this point south to Pehehoni Point the shoreline bluff is spectacular with an abundance of sea-caves and large, natural arches.

South of Kipu Rock the substrate is 100% boulder covered, mostly one-half meter in diameter. This situation lessens, and Moinui Point has an 80% smooth, bare volcanic floor. The boulders are 60% algae encrusted, and up to 30% covered by corals. The only area from Palemano

Point to Kanoni Point where sand was observed was along the north face of Kanoni Point. Here several one-meter patches of gravelly sand appear.

South of Kanoni Point the bottom is a gently-sloping aggregation of broken rock with 5% coral coverage, over 50% algae encrusted. Occasionally the bare volcanic crust is exposed for periods.

At Pehehoni Point, the substrate at a depth of 10 meters is sand with occasional large boulders and numerous smaller rocks. The cover is 20% *Pocillopora* and 10% castle *Porites*. Moving into Honaunau Bay (Fig. 10), sand is no longer present and finger *Porites* (*P. compressa*) is seen.

Sand patches are uncommon along the north face of Honaunau Bay: finger *Porites* becomes more abundant, and *Pocillopora* drops off completely. Enormous colonies of bright-yellow castle *Porites* appear. Colonies this huge and colorful had not been previously observed south of Palemano Point. Finger *Porites* grows at the colony fringes. Near the head of the bay, finger *Porites* is abundant at a depth of four meters. Specimens of this species are rare in Kealakekua Bay at such shallow depths.

The southern face of Honaunau Bay is not traversible by boat. Puuhonua Point (Fig. 11) drops off sharply with many vertical faces nearly breaking the surface in places. These dramatic vertical faces are unique to the entire region surveyed, and a rich fish population is present. The south side of the point flattens out somewhat, is 80% bare at a depth of 10 meters.

The shoreline drops immediately to 25 feet off the park headquarters, and the slope is then gradual to 35 feet. This shallower belt is 80 per cent exposed; 10 per cent dominated by castle *Porites* and 10 per cent by *Pocillopora*. At a depth of 40 feet the coral cover is increased to 60 per cent, mostly by castle *Porites*. Sand patches are present throughout. The outer slope starts at 45 feet, and cover is finger *Porites* amongst abundant patches of sand.

North of Alahaka Bay the bottom breaks up with wide fissures, ledges and underwater caves. Some sand patches appear toward Alahaka Bay, but the bay itself is a flat lava shelf with little sand in evidence at shallower depths.

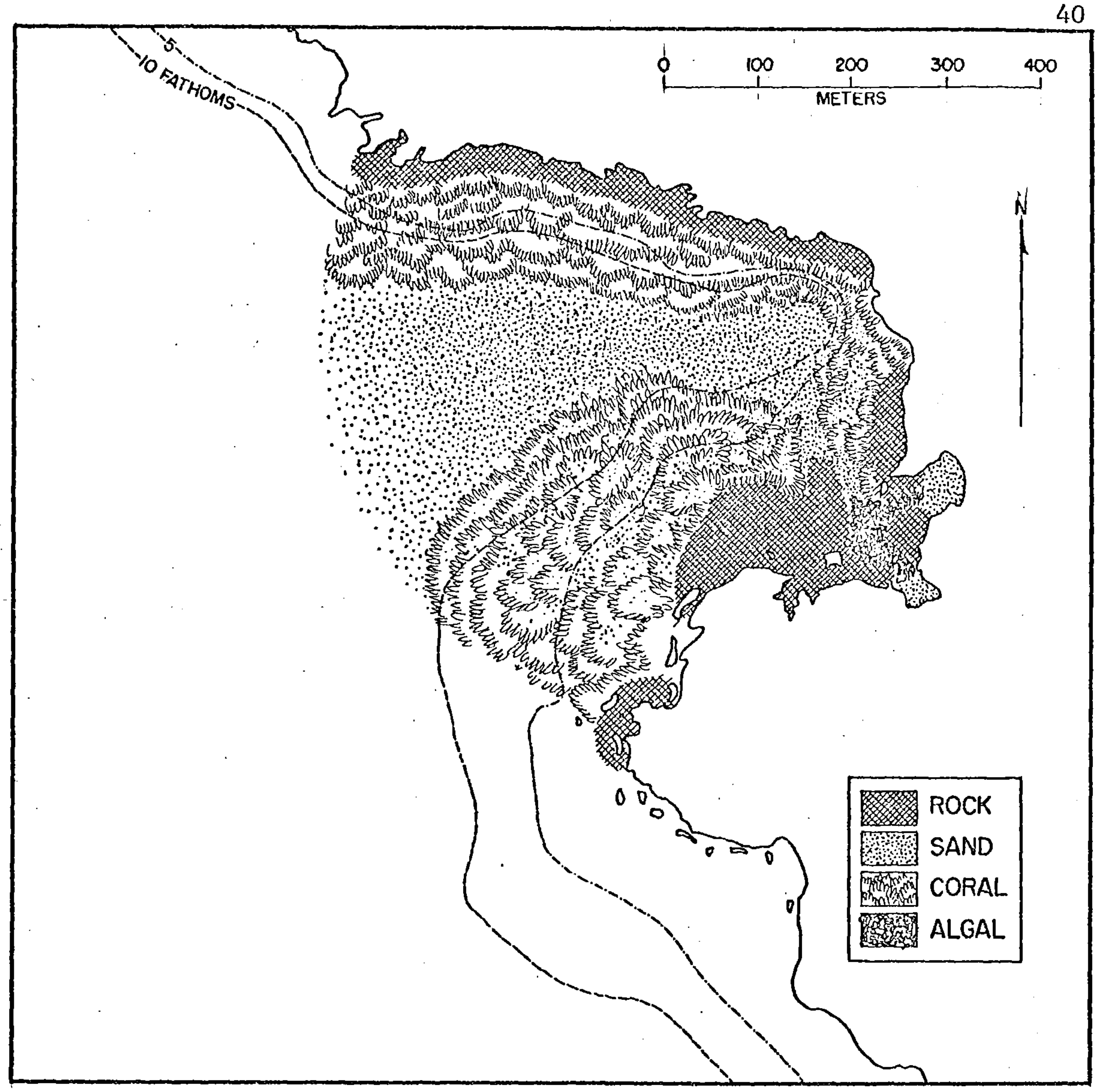

FIGURE 10. A schematic chart of Honaunau Bay showing predominance of bottom types. The north and east shorelines drop off immediately to 12 feet. A shallow lava bench extends from the south shore and then drops abruptly to 15 feet. The bay is very flat from 15 to 25 feet. The slope steepens beyond 30 feet and again beyond 60 feet; it is directed northwest not outward due to a very deep trench which lies along the north shore. The sides of the trench are coral covered, the bottom is sand. Sand patches occur sporadically in the south half of the bay. There are two sandy beaches in the southeast reach of the bay, and this region is otherwise dominated by algae.

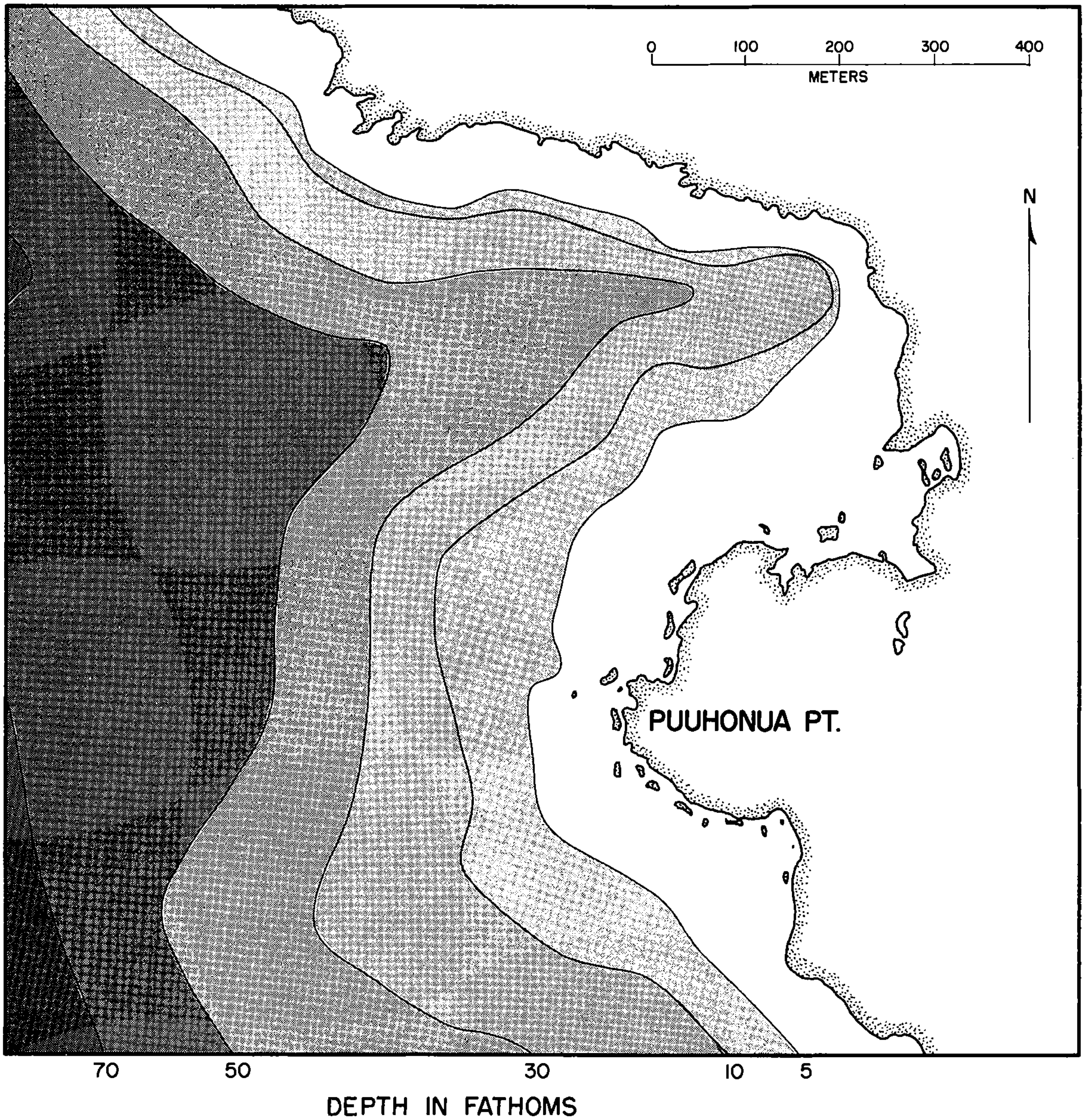

FIGURE 11. A chart of Honaunau Bay showing depth contours in fathoms.

The northern half of the bay contains few boulders on the flat shelf, whereas boulders are common on the southern half of the bay. A dark grey sand coats much of the boulders, and algal turfs are also present. The coral varies at five fathoms depth from 80 per cent at the northern and southern ends of the bay to 30 per cent along the head of the bay and in the vicinity of the large sea cave where Pali Alahaka meets the sea. In general there is three times as much cover by castle Porites as by Pocillopora at five fathoms. Pocillopora is dominant at shallower depths. In terms of both diversity of species and population sizes, fish are strikingly more conspicuous here than in Honaunau Bay.

According to local fisherman, the substratum is sandy on a line from Miana Point to Loa Point at depths from 20 to 30 fathoms. The sand belt extends shoreward to 500 m off Puuhonua Point, 100 m off the park headquarters and 150 m off Alahaka Bay. A broad and elliptical sandy area overlain with broken finger coral rubble extends from beyond surface visibility to a shallow depth of 45 feet near the center of the bay.

Sand remains absent at depths of 30 feet south of Alahaka Bay to Loa Point: castle Porites is the dominant coral and varies in abundance from five to 10 per cent cover. The bottom is a smooth basalt shelf with large boulders here and there. Some large sea caves and arches are present at Loa Point.

2. Underwater transects run at Honaunau Bay and Alahaka Bay.

Four 100-meter underwater transects (Fig. 12) were established at Honaunau Bay for making quantitative estimates of coral and urchin populations. The results are presented later in Chapters 8 and 10, respectively. A single transect for comparative purposes was established at Alahaka Bay.

The general topographical situation at Honaunau Bay (Fig. 13) is a shoreline which drops off abruptly to a depth of 12 feet. The bay is then very flat to 30 feet, after which the slope quickens. It steepens again at 60 feet. Since the transects extended 100 meters out from various points along the shoreline, the balance of sampling was over this broad, nearly flat region from 12 to 30 feet. Of a total of

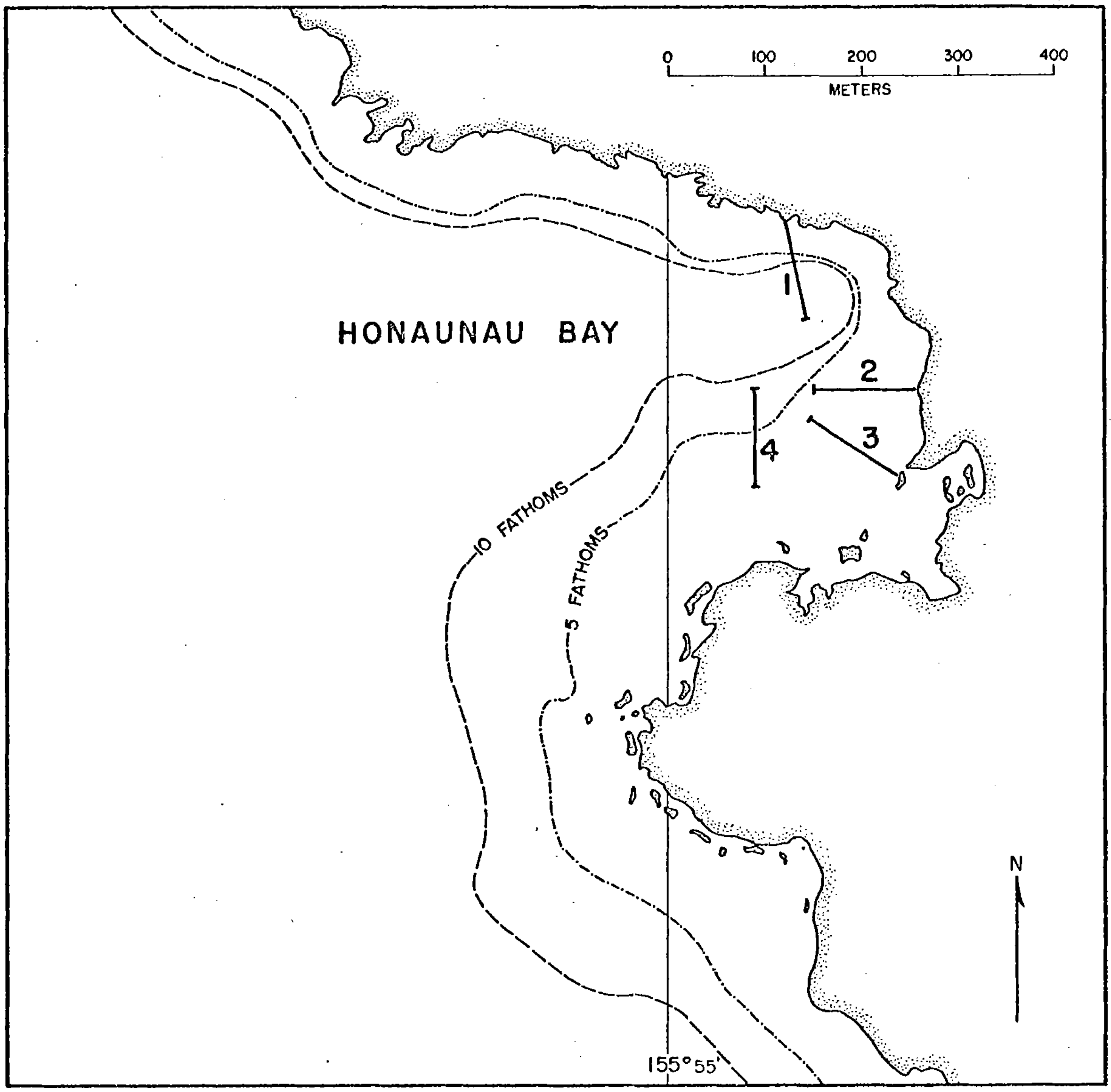

FIGURE 12. Underwater Transects 1 through 4, Honaunau Bay.

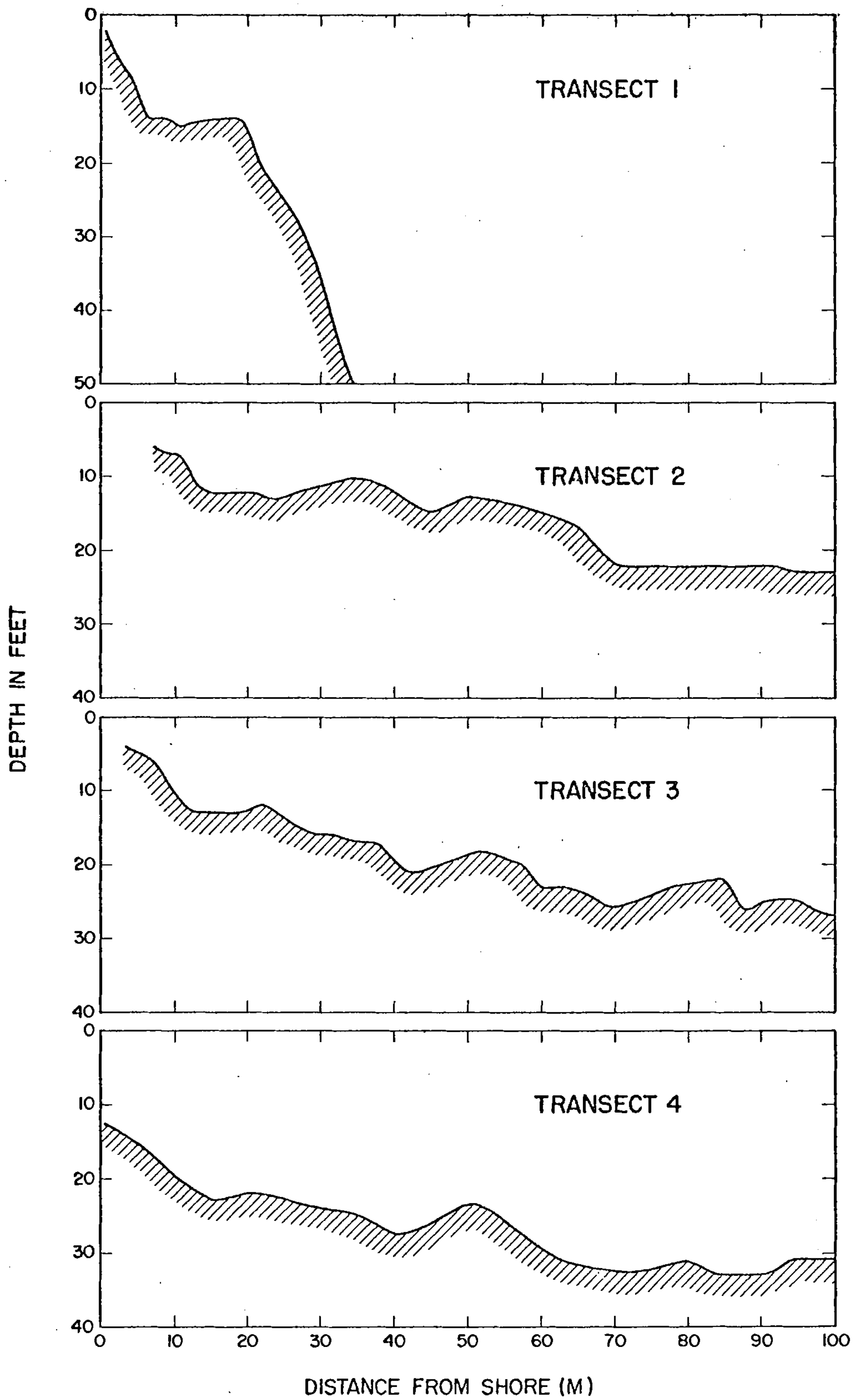

FIGURE 13. Depth profiles of underwater Transects 1 through 4, Honaunau Bay.

91 quadrat samples made in Honaunau Bay, 71 were at depths within this range. Almost no sampling was done at depths less than 10 feet or exceeding 40 feet.

The following is a general description of each of the five transects and their bearings. Quantitative data are presently elsewhere.

Transect 1 begins along the north shoreline of Honaunau Bay 155.0° magnetic to Hale-o-Keawe. It terminates 155.0° magnetic from the transect origin. The shoreline drops off abruptly to a 40-foot-wide shelf at a depth of 14 feet. The inner fringe is dominated sparingly by *Pocillopora meandrina*; the bulk of the shelf by castle *Porites* (*P. pukoensis*). The floor then drops rapidly (Fig. 13) to 110 feet at the sandy bottom of a deep trench. The sides of the trench are densely covered with *Porites* (*P. compressa*), although castle *Porites* remains present. The red alga, *Tolypiocladia*, is common in finger coral interstices. The topography here closely resembles that at Kaawaloa Cove, Kealakekua Bay.

Transect 2 begins (Fig. 13) on the eastern shoreline of Honaunau Bay, 185.0° magnetic to Hale-o-Keawe and terminates at a point 262.0° magnetic from the origin. The end point lies 155.0° to Hale-o-Keawe. The shoreline drops off abruptly to 12 feet, and the bulk of the transect crosses a flat shelf from 12 to 23 feet in depth over assorted concentrations of castle and finger coral. Some sand patches are present.

Transect 3 begins (Fig. 13) at Puuehu rock and runs on a line 290.5° from the origin. It crosses several sand patches so that certain quadrats are without biotic cover. This transect lies along the mouth of contaminated Keone-eli cove. From 10 to 40 per cent of the castle coral in the shoreward 35 meters of the transect was encrusted with assorted plant and animal growths and considered dead. Data obtained from the contaminated portion of this transect are contrasted in Chapter 8 at length with Transect 2 which lies in cleaner waters.

Transect 4 begins (Fig. 13) at the edge of a drop-off on the south shore of Honaunau Bay, 119.0° magnetic to Hale-o-Keawe and terminates at a point 347.0° magnetic from the origin. It terminates 140.0° to Hale-o-Keawe. The bulk of the transect lies across extensive growths of finger coral.

Transect 5 begins (Fig. 14) several meters in from the northwest extremity of Alahaka Bay. It terminates at a point 153.0° magnetic from the origin on the lip of a huge sandy region stretching out to the south and west. This was the most exposed area sampled by transects, and the crust is more exposed here than at Honaunau Bay. Coral cover on the lava crust varies over the balance of the transect from 60 to 80 per cent. In Honaunau the lava crust is rarely exposed except at the shoreline, and those areas not coral dominated are sandy.

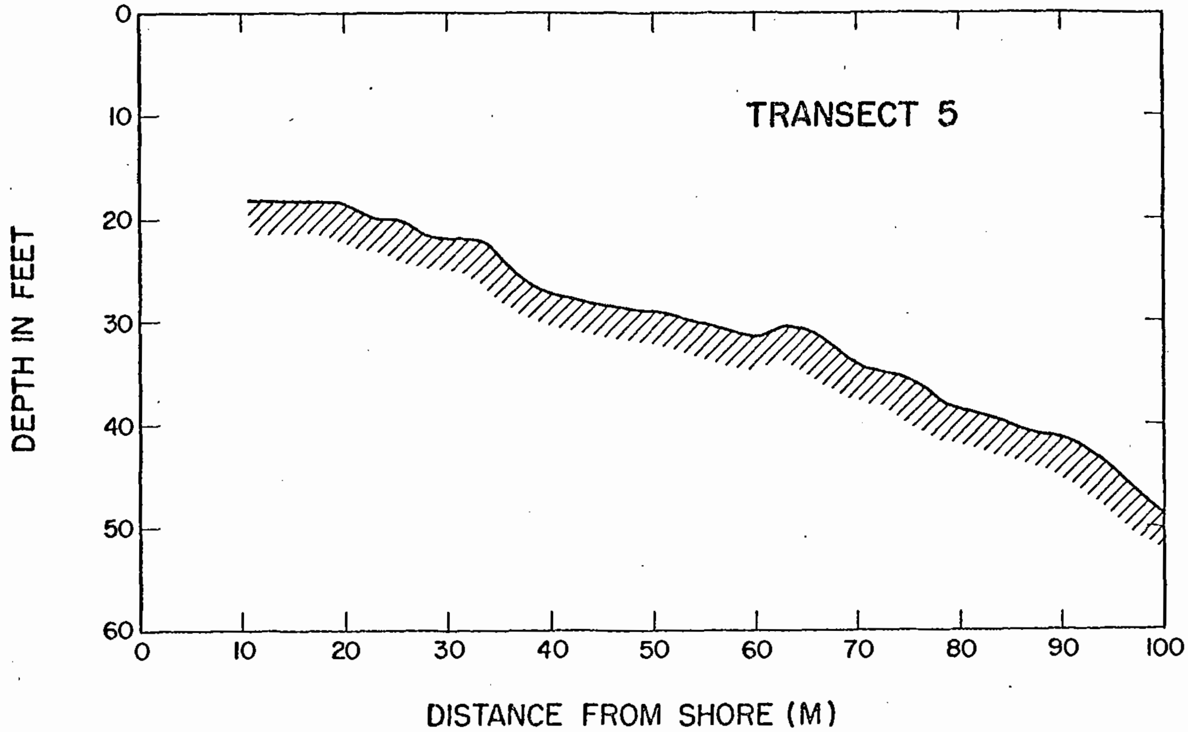

FIGURE 14. Depth profile of underwater Transect 5, Alahaka Bay. The 100-meter line heads 153° magnetic from the northwest extremity of the bay.

Chapter 6

PLANKTON

Plankton tows were made at several stations in the environs of Kealakekua Bay (Fig. 15) and Honaunau Bay. A 45-cm diameter conical "Norpac" style plankton net with a pore size of 300 microns was used. It was towed by an outboard motorboat in a figure-eight pattern, at a depth of one meter and speed of approximately 5 m.p.h.

The zooplankton catch was correlated neither with time of day nor tide height in the present survey. A total of 18 tows was run, 11 during late fall, 1968, and seven in early spring, 1969. In general, spring tides yielded denser populations. However, due to the low number of replicate tows, available from only Stations 15 and 19, it is felt that no more than preliminary conclusions can be taken from the work presently completed.

The data obtained (Table 3) indicate the region off Cook's Monument in Kaawaloa Cove (Sta. 12) to be the richest area in Kealakekua Bay in biomass of zooplankton. At this station, 146 mg wet weight zooplankton per cubic meter sea water was collected, which compares (Sta. 18) with ten mg in the open area 200 meters offshore midway between Kealakekaua and Honaunau Bays. A five-tow average of 187 mg/m^3 was gathered at the head of Honaunau Bay. This mean density of zooplankton in the surface layer is greater than was recorded anywhere in Kealakekua and indicates that of the two bays, Honaunau is the more productive.

The region off Napoopoo Beach (Sta. 15) was towed on three different dates, and the results indicated considerable variation in the density of the zooplankton population present at these times; ranging 19 to 129 (mean 77) mg/m^3 sea water.

It was noted in fall, 1968, that stomachs of the midwater daytime plankton-feeding fish species, Chromis ovalis and C. verator, taken in Kealakekua contained little food by comparison with others caught near Oahu, and it was thought this might reflect a paucity of zooplankton.

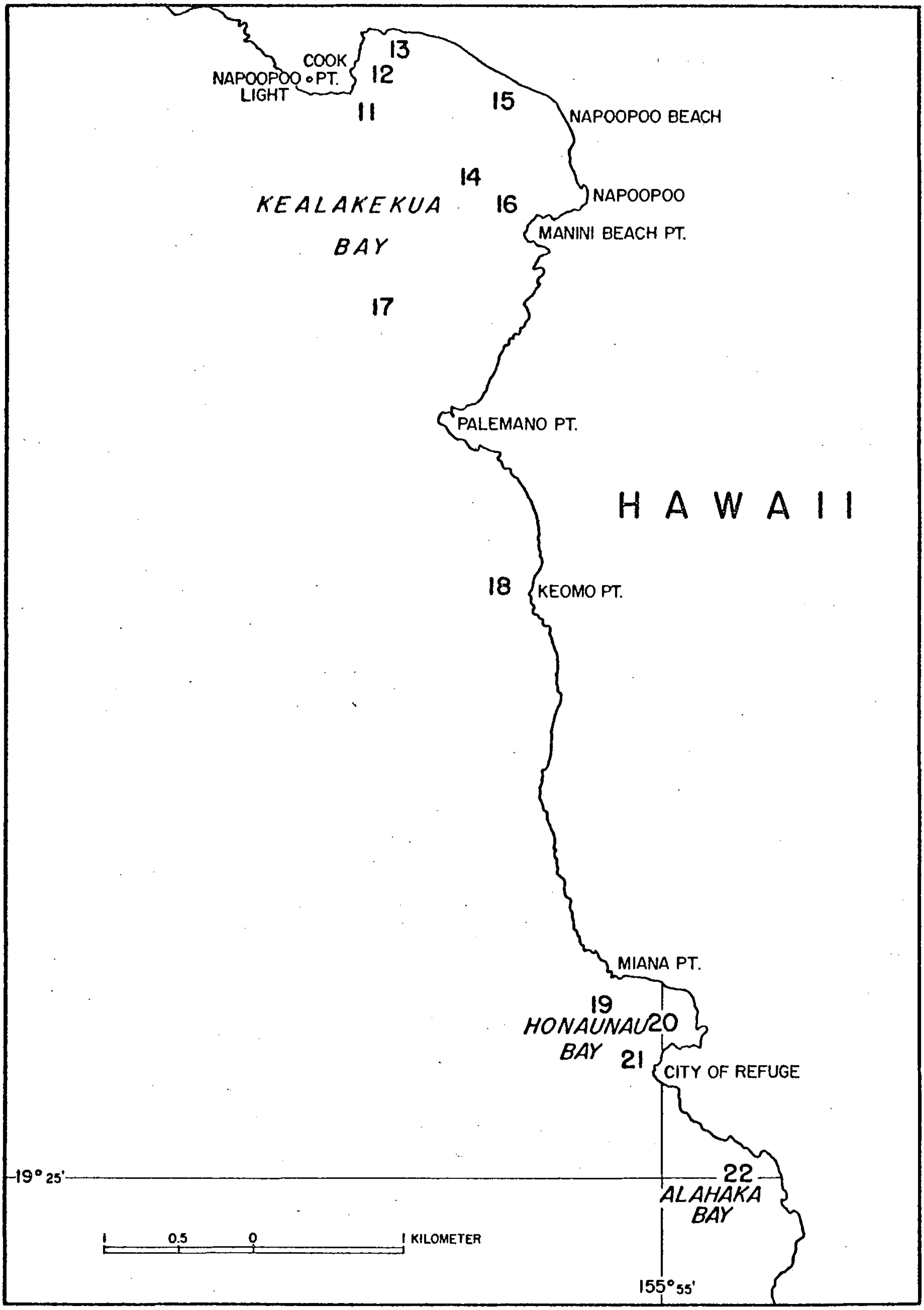

FIGURE 15. Plankton tow stations. Stations 11 through 22 are indicated and their positions are described in the text.

TABLE 3. The settling volume and wet weight of zooplankton per cubic meter sea water in Honaunau Bay and environs.

Station number	Time	Tide	m^3 sampled	ml/m^3	mg/m^3
11	0900 19-X-68	+0.4 ebb	15.5	0.23	72
12	1400 2-XI-68	+1.4 flood	39.4	0.48	146
13	1400 19-X-68	+1.4 falling	19.5	0.33	102
14	1000 19-X-68	+0.6 rising	16.1	0.22	74
15a	1100 30-X-68	+1.9 flood	40.1	0.39	129
15b	1100 31-X-68	+1.4 rising	26.8	0.06	19
15c	1000 2-XI-68	+0.6 rising	39.0	0.24	84
16	0930 19-X-68	+0.5 rising	15.7	0.13	41
17	1000 30-X-68	+1.6 rising	47.2	0.06	02
18	0900 30-X-68	+1.3 rising	30.1	0.03	10
19a	1000 31-X-68	+1.1 rising	41.4	0.23	81
19b	1305 6-III-69	+0.1 rising	17.1	0.74	127
19c	0945 11-III-69	+0.4 rising	18.9	0.76	133
19d	1440 11-III-69	+0.1 ebb	21.5	2.37	403
19e	1405 12-III-69	+0.3 falling	16.6	1.20	192
20	0815 6-III-69	+0.7	16.3	0.90	150
21	1015 6-III-69	0.0 falling	15.5	0.64	110
22	1310 11-III-69	+0.2 falling	23.9	0.88	141

Station designations are described below.

Station 11 is on a line between Manini Beach Point and Napoopoo Light, 150 m off Cook Point.

Station 12 is 80 m offshore between Cook's Monument and Umi's Well.

Station 13 is located 100 m off a talus slope at the west end of Kaawaloa Cove.

Station 14 is positioned (in degrees magnetic) 280° to Napoopoo Light, 115° to the church spire and 242° to the tip of Palemano Point.

Station 15 is 50 m off the center of Napoopoo Beach. Tows were made at this station on three different occasions, and the samples are indicated as 15a, 15b and 15c, respectively.

Station 16 is positioned on a line between Manini Beach Point and Napoopoo Light, 150 m off Manini Beach Point.

Station 17 is situated on a line between Palemano Point and Napoopoo Light, directly off (due west of) Manini Beach Point.

Station 18 is positioned 322° to Napoopoo Light; 200 m offshore in front of a fishing shanty at Keomo Point.

Station 19 is as close to the head of Honaunau Bay as towing comfortably allows. The depth varies from three to five fathoms.

Station 20 is midway between Hale-o-Keawe and Miana Point in Honaunau Bay. The depth here is 10 fathoms.

Station 21 is 100 m offshore in front of the City of Refuge N. H. P. headquarters.

Station 22 is at the head of Alahaka Bay.

Chapter 7

ALGAE

General considerations and some comments

Seaweeds in Honaunau Bay are largely restricted to shoreline habitats. Excepting in Keone-eli cove, there are no seaweed beds at all below the low tide line. Indeed, it appears the normal benthic algal role is replaced by zooxanthellae (dinoflagellates) in the extensive coelenterate coral beds.

The lack of seaweeds in Honaunau Bay is related to low fertilizer concentrations. In Waikiki, by way of comparison, beds of seaweed are extensive, coral sparse. However, it would appear there is a very suitable environment for heavy cover, particularly in the southern reaches of the bay.

Below the littoral zone (see Doty, 1957, for definitions of intertidal zones used in this chapter) the only area of the bay dominated by algae is Keone-eli cove. Diatoms are particularly abundant here. Organic-rich fresh water from two nearby cesspools enters the bay at this point but flushing must negate its usual effect.

Algal beds are often conspicuous in areas where fresh water and fertilizer are introduced. With cesspool effluent percolating into Honaunau Bay and subsequent diatom seaweed populations appearing, natural food for the native organisms decreases. Thus fish and other animal populations decrease to the extent they do not consume the new algal populations or the pollution material directly.

The principal among green pollution indicators is the presence of an algal community dominated by the genus Ulva. Large green areas of this sea lettuce, often becoming off-white or yellowish in part, could be expected to develop if a significant amount of fresh water and fertilizer were to percolate into Honaunau Bay, or even if processed sewage were to be furnished.

The development of a pollution-type marine community in Honaunau Bay would mean loss of much of the present Hawaiian marine life, and in few other areas in this marine life more readily accessible.

A marine shore area in balance receiving quantities of fertilizer flushed in with fresh water adapts to the new conditions. The expected pattern is for a series of near-irreversible changes to occur. The first changes to be seen are in the microscopic algal organisms, those essential to the larval animal stages and utilized (as zooxanthellae) by coral adults. The results are newly dominant species of the short-lived, frequently reproducing kinds. In this case, they will be diatoms and benthic algae relatively insensitive to or stimulated by the addition of fresh water and the fertilizers derived from sewage. In the tropics the benthic species are usually members of the Ulvaceae: Enteromorpha if a steady supply of fresh water is involved, Ulva if the fresh water is less or periodic and contains increased nitrogenous wastes. Thus it is that a splash of green from these seaweeds in front of a residence or bathouse indicates pollution.

An Ulva community is usually strangely sparse in animal life or much of any living material other than the seaweed Ulva itself. Many explanations have been offered for this, but wide variations in the oxygen content of the water and the production of toxic materials are two which do function to exclude most animals.

Caution must be exercised, however, against over-generalizing and against reliance on but single indicators. Taken by itself, the presence or absence of sea lettuce tells us little. In fact, Ulva fasciata is present in varying quantities along the entire shoreline from Miana Point to Alahaka Bay, often dominating the high littoral zone. It is bright green, not yellow, and grows amongst a rich assortment of other species.

In June 1968 and March 1969 four study areas of shoreline Ulva fasciata were established and documented with color photography. Study Area 1 was established in June 1968 and is just north of Puuehu rock in Honaunau Bay, and replicate photographs were taken in March 1969. Ulva fasciata then covered much of the upper littoral lava beach which nine months previously had been dominated by Ahnfeltia concinna. A belt of Sargassum echinocarpum in the lower littoral zone was also largely replaced; to a lesser degree by Ahnfeltia and to a greater extent by a thick dark-red mat of Ceramium sp. and Laurencia subsimplex growing epiphytically on _Valonia aegagropila_.

Shoreline algal Study Areas 2 through 4 were established in March 1969. Area 2 consists of the shore of Keone-eli cove, Study Area 3 is the shore fronting Hale-o-Keawe and Area 4 is the intertidal zone fronting the park headquarters. At all these stations luxurious growths of _Ulva_ were present and photographed. On the rock shores a normal distribution of _Pterocladia_ below low tide line and _Ahnfeltia concinna_ above this level are found. Tangled in them and conspicuous at low tide is the dark green network, _Ulva reticulata_. This later alga is much lighter green in waters of normal fertilizer content. These three seaweeds are those most abundantly washed in onto this elegant though small beach. Elsewhere in the world (_e.g._ Gamulin-Brida _et al._, 1967) report _Ulva_ and _Pterocladia_ to become abundant as pollution increases.

As previously mentioned, the great majority of benthic species are restircted to the shoreline. The list of species observed (Table 4) is brief. Three broad classes of littoral habitats at Honaunau are recognized on the basis of exposure: exposed shorelines, partially sheltered shorelines and protected shorelines. The following observations are grouped under these headings. As benthic algae undergo seasonal succession, it should be noted that the present survey was conducted during the month of March.

TABLE 4. Algal species recorded from Honaunau Bay and environs, March 1969.

Cyanophyta:	Calothrix sp.
	Lyngbya sp.
	Trichodesmium sp.
Chlorophyta:	Acetabularia Moebii
	Boodlea sp.
	Chaetomorpha antennina
	Chaetomorpha sp.
	Cladophora sp.
	Cladophoropsis adhaerens
	Dictyosphaeria cavernosa
	Enteromorpha spp.
	Halimeda discoidea

TABLE 4 (continued)

(Chlorophyta:)	Microdictyon setchellianum Ulva fasciata Valonia aegagropila
Chrysophyta:	Amphiprora sp. Amphora sp. Cocconeis sp. Melosira sp.
Phaeophyta:	Chnoospora pacifica Colpomenia sinuosa Ectocarpus breviarticulatus Ectocarpus sp. Padina japonica Lobophore variegata Sargassum echinocarpum Sargassum polyphyllum Sphacelaria tribuloides Turbinaria ornata
Rhodophyta:	Acrochaetium sp. Ahnfeltia concinna Alsidium sp. Centroceras clavulatum Centroceras minutum Ceramium sp. Champia parvula Erythrotrichia sp. Galaxaura sp. Gelidiella acerosa Gelidium sp. Gelidiopsis scoparia Griffithsia sp. Hemitrema sp. Herposiphonia sp. Hypnea sp. Jania sp. Laurencia subsimplex Laurencia spp. Melobesioid sp. (unidentified) Polysiphonia sp. Porolithon onkodes Pterocladia capillacea Tolypiocladia glomerata Wurdemannia miniata

A single and curious exception to the three shoreline areas which might be mentioned is an exposed, tiny sandy beach 500 m south of the park headquarters. The low tide salinity is 34.5 parts per thousand at the water's edge. The lava here is bright green which contrasts strikingly to the balance of the shoreline, and consists largely of a single species of Enteromorpha forming a tight, green turf under one half cm in height. The sub-dominant species is Ulva fasciata. A gelidioid and Polysiphonia sp. are also present. The Enteromorpha diagnostically is similar to E. prolifere (Mueller) J. Agardh as Chapman (1956) describes it. However, his New Zealand specimens are up to 0.5 m in length and two mm in width whereas the present specimens do not exceed three mm in length and are 50 microns wide.

Offshore habitats

The dominant alga in the Honaunau environs in terms of area coverage is a melobesioid encrusting sheltered surfaces of finger coral (Porites compressa). The second dominant is the red alga Tolypicladia glomerata. It also grows in finger coral interstices and is exceedingly abundant on all the steeper slopes of the bay from three to at least 15 fathoms depth. However, this species is also found in trace quantities along the entire shoreline, in both exposed and protected areas.

Halimeda discoidea and Turbinaria ornata were found in interstices of castle coral (Porites pukoensis), the latter in more exposed areas such as along the shoreline north and south of Honaunau Bay.

Algal turfs and encrustments occur commonly on boulders and on dead coral, and in more exposed regions may contain rich floral aggregations of green, red, brown and blue-green algae. For instance, a one-half cm high brownish-colored mat on boulders near Keomo Point consisted principally of Laurencia sp., with varying amounts of the genera Herposiphonia, Erythrotrichia, Acrochaetium, Pseudobryopis (?), Sphacelaria and Calothrix represented. A dark yellow surface scum of the blue-green planktonic alga, Trichodesmium, is often distributed offshore.

Exposed shorelines

On intertial vertical faces of exposed points of land meeting the sea, a meter-wide pink band of the encrusting melobesioid Porolithon onkodes capped with Ahnfeltia concinna is clearly apparent. Cowries feed nocturnally in the Ahnfeltia. This condition is met north of Miana Point and along the head of Alahaka Bay, at one or two points along the north shore of Honaunau Bay and at several points between Honaunau Bay and Alahaka Bay.

In areas of heavy surf without vertical faces a characteristic algal distribution was noted, occurring along the north shore of Honaunau Bay and Alahaka Bay, and between Puuhonua Point and Alahaka Bay.

Sargassum echinocarpum dominates the lower littoral fringe. A. Laurencia sp. is also abundant in most areas and Porolithon onkodes is present. The littoral zone is variously dominated by Ahnfeltia concinna, Ectocarpus sp., mats of Ceramium sp. on Polysiphonia sp. in turn on Alsidium sp., and of Ceramium sp., Griffithsia sp. and Champia parvula on Dictyospaeria cavernosa. Ulva fasciata is always present in some quantity and often dominates upper littoral areas between Honaunau Bay and Alahaka Bay. It is sub-dominant along the north shore of Honaunau Bay. Galaxaura is very common in the upper littoral zone at Puuhonua Point; and here a supralittoral zone is dominated by Ectocarpus breviarticulatus and Ectocarpus sp., sub-dominated by Cladophora sp. and Padina japonica.

The following species were also observed in the littoral zone: Boodlea sp., Centroceras minutum on Jania sp., Ceramium sp. on Lobophore variegata and on Sphacelaria sp., Chnoosphora sp., Cladophoropsis adhaerens, Gelidiopsis scoparia, Hemitrema sp., Herposiphonia sp., Hypnea sp., Microdictyon setchellianum, Padina japonica, Pterocladia capillacea, Sargassum polyphyllum, Tolypiocladia glomerata and Valonia aegagropila.

Partially sheltered shorelines

The east shoreline and south shoreline west of Hale-o-Keawe in Honaunau Bay are partially sheltered from high surf, and characteristic algal species are found here. Sargassum echinocarpum dominates the lower littoral fringe, but is far less abundant than along exposed shorelines.

Porolithon onkodes is sparse. The upper littoral zone is dominated by Ulva fasciata. Ahnfeltia concinna is sub-dominant. Mats of Ceramium sp. and Laurencia subsimplex on Valonia aegagropila are common. Pterocladia capillaces dominates the area between the lower littoral Sargassum fringe and the upper littoral Ulva-Ahnfeltia zone.

The following species were also recorded in the littoral zone: Centroceras minutum on Jania sp., Chaetomorpha antennina, Colpomenia sinuosa, Dictyosphaeria cavernosa, Gelidiella acerosa, Hemitrema sp., Herposiphonia sp. on Hypnea sp., Laurencia sp., Microdictyon setchellianum and Wurdemmannia miniata.

Protected shorelines

The shorelines of Kapuwa'i cove, Keone-eli cove and a shallow inlet west of Hale-o-Keawe, all in Honaunau Bay, receive a minimum of wave action. The dominant upper littoral green seaweeds at Kapuwa'i are Ulva recticulata and Enteromorpha sp. These were not observed in keone-eli where dominance was expressed by Ulva fasciata and by a green shoreline scum. The scum consisted of filamentous diatom colonies of the genus Amphiprora, but the diatom genera Melosira, Amphora and Cocconeis were also represented.

Growing in the midlittoral zone at Kapuwa'i is a turf of Wurdemannia miniata underlying Ceramium sp. Also observed were Gelidium sp., Chaetomorpha sp. and a negligible quantity of Ulva fasciata. Along the shorelines of both Kapuwa'i and Keone-eli are abundant brackish pipipis (Theodoxus neglectus) and mussels (Isognomon californicum).

The dominant sublittoral benthic alga in both coves to a depth of one half meter is Centroceras clavulatum. The reddish 3.5 cm fronds are tipped with 1.5 cm diatom filaments of the genus Amphiprora. The collection is most abundant in Keone-eli which also receives far more organic matter than does Kapuwa'i due to the proximity of two cesspools. Nitrate and phosphate levels (Table 2) are highest in Keone-eli. These pollution factors undoubtedly influence the heavy algal growth. The diatom epiphytes of Kapuwa 'i are light brown in color, whereas in Keone-eli they are deep green, contrasting strikingly with the red

Centroceras.

Other benthic genera noted in Keone-eli were Chnoospora, Chaetomorpha, Acetabularia, Cladophoropsis and Lyngbya. The last genus, a blue-green, was not observed in Kapuwa'i, and is known to tolerate high levels or organic matter.

From the depth of one half to two meters, the substratum of Keone-eli cove is blanketed by a species of Gelidium, again fringed with epiphytic diatom filaments. In this case the filaments are mostly of the genus Melosira. Beneath the Gelidium, exposed basalt surfaces are nearly 100 per cent encrusted with reddish melobesioid algae. Porolithon onkodes was identified from fertile material.

It is generally felt that coral species dominating Honaunau Bay tolerate only low levels of phosphate, and as noted in Chapter eight, the approach to Keone-eli is relatively devoid of coral. The coral present is largely encrusted with plant and animal growths which is to say it is dead or dying. Presumably lack of competition from coral is the reason melobesioid algae are able to flourish here, as excepting on intertidal basalt faces Porolithon onkodes is scant in Honaunau Bay.

The living coral present in Keone-eli consists of genera (e.g., Polythoa) not common to the bay proper.

As pointed out in Chapter 10, relatively few sea urchin species were noted at the entrance to Keone-eli: Echinometra mathaei dominates and E. oblonga is present. The shallow, protected inlet west of Hale-o-Keawe, by comparison, has urchins abundant at depths of under one meter. Tripneustes gratilla and Echinometra mathaei dominate and Echinothrix spp. and Heterocentrotus mamillatus are also common.

The algae in this inlet are more representative of the nearby shoreline than of other protected habitats. No scummy diatom growths were seen, and the benthic species listed by order of dominance were Ulva fasciata, Centroceras minutum on Hypnea sp., Ceramium sp. on Jania sp., Dictyosphaeria cavernosa, Laurencia sp. and Valonia aegagropila. Also observed were Tolypiocladia glomerata, Hemitrema sp. and Gelidiella acerosa.

Chapter 8

CORAL

Introduction

Coral populations in Honaunau Bay and Alahaka Bay were quantitatively surveyed in March 1969. Four 100-meter underwater transects (Figs. 16-20) were established at Honaunau Bay and one was established at Alahaka Bay. As data gathered were not restricted to corals, physical specifications of the transects are presented in Chapter 5 on underwater topography.

Methods

Surveying was conducted by a team of SCUBA divers using a modification of the point-quadrat method of sampling. A 1 m^2 steel quadrat was placed at regular intervals along each transect line, and depth was noted. The species of coral lying directly under each corner of the quadrat was recorded separately, and those within the quadrat were recorded qualitatively, as present or absent. The percentage cover of each coral species was then determined with the following formula:

$$\frac{\text{No. of quadrat corners species found under x 100}}{\text{Total no. of quadrat corners sampled}} = \text{\% cover for species in question.}$$

Results

Both absolute and relative abundance (Table 5) of coral species recorded in Honaunau Bay and Alahaka Bay were determined. However, several species were present but not observed on transect lines and hence are not included in Table 5. They are Fungia scutaria, observed near the shallow end of Transect 1, and Sarcothelia edmondsoni and Polythoa sp, both observed at a depth of less than one fathom in contaminated Keone-eli cove and elsewhere. Species not observed at all on this survey, but found in varying abundances at nearby areas along

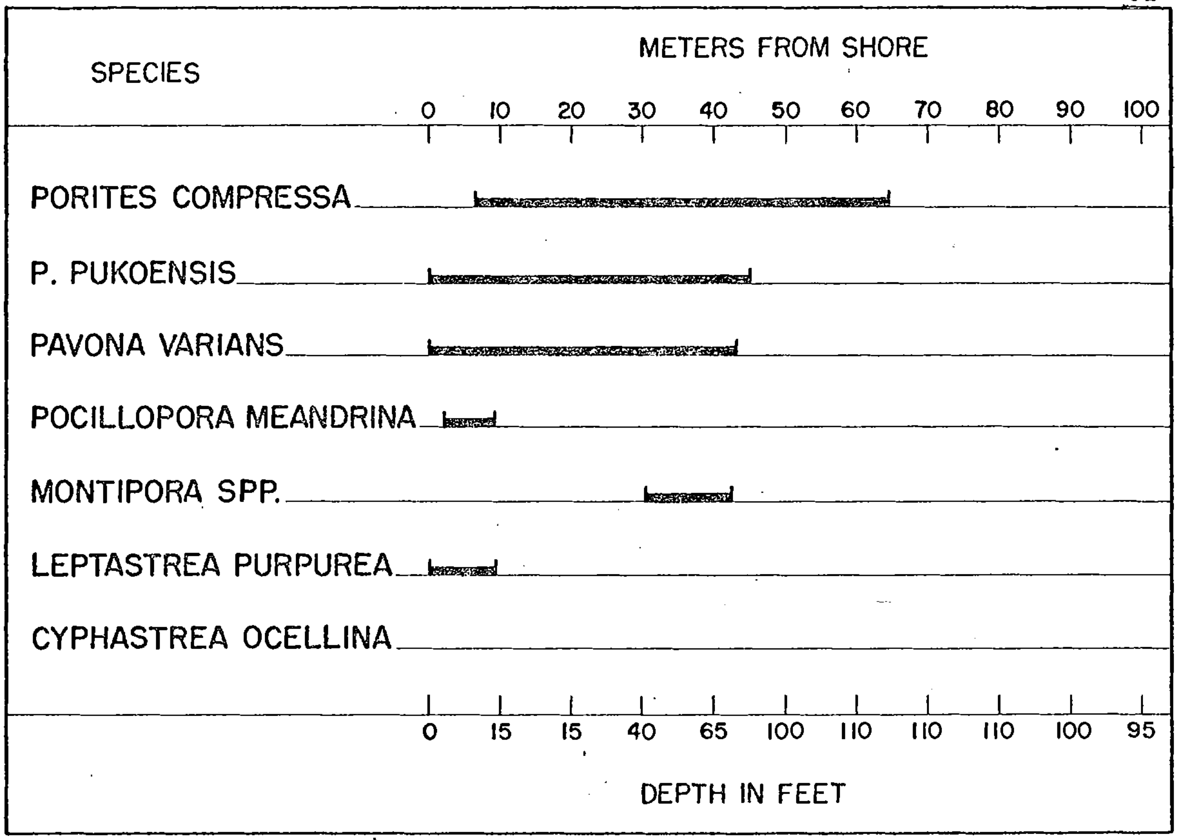

FIGURE 16. Coral composition on Transect 1, Honaunau Bay.

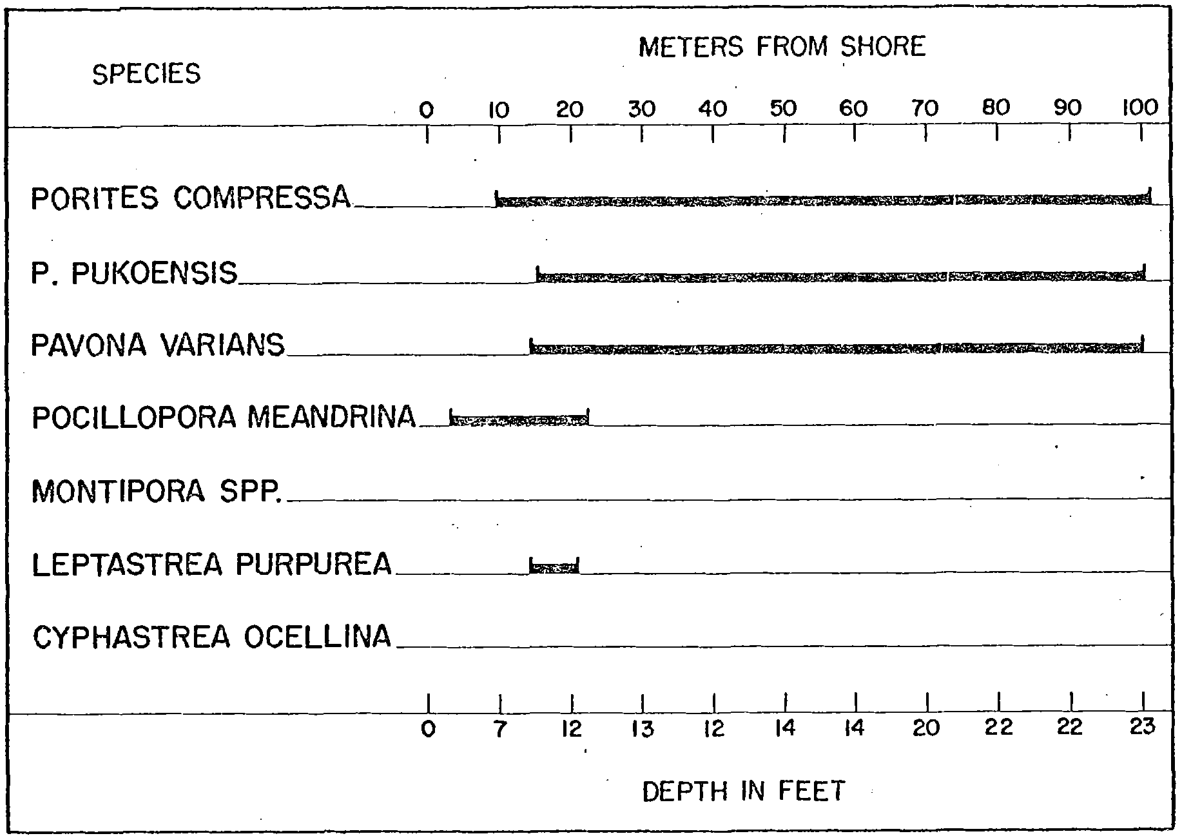

FIGURE 17. Coral composition on Transect 2, Honaunau Bay.

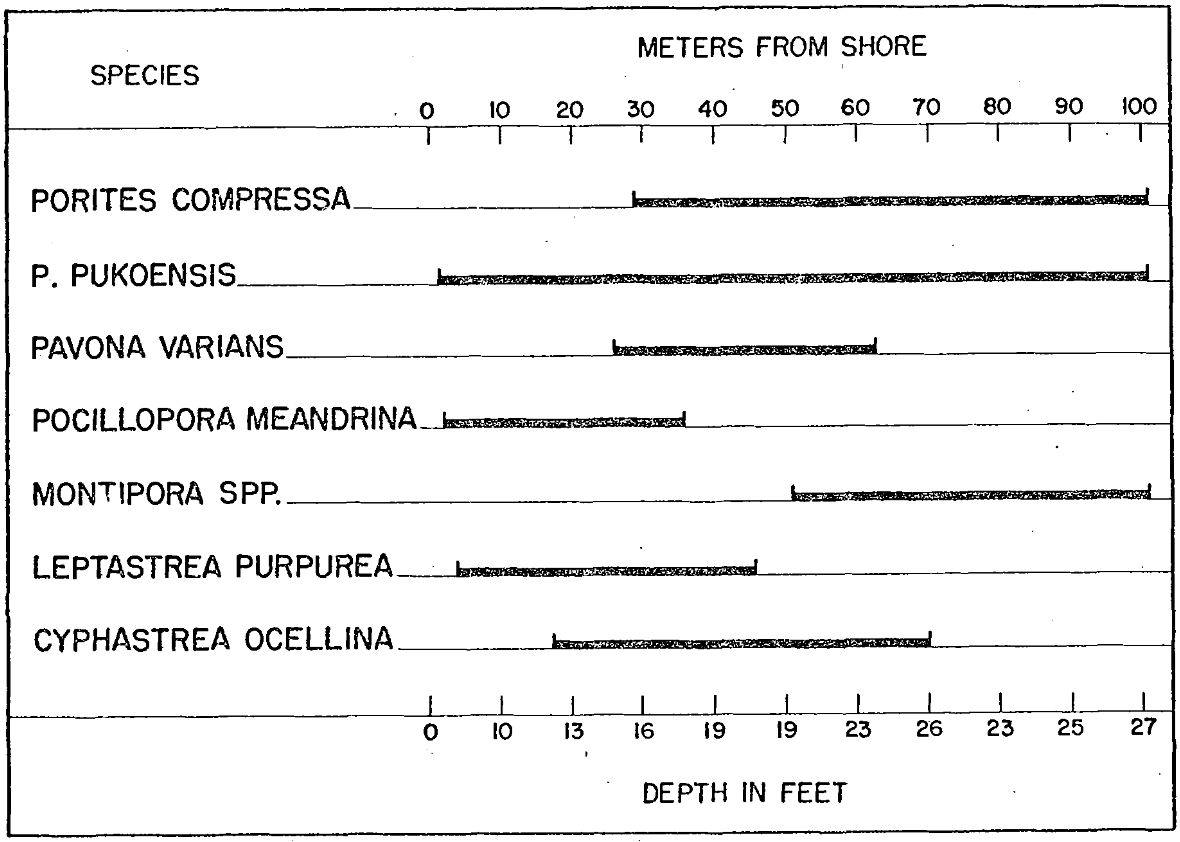

FIGURE 18. Coral composition on Transect 3, Honaunau Bay.

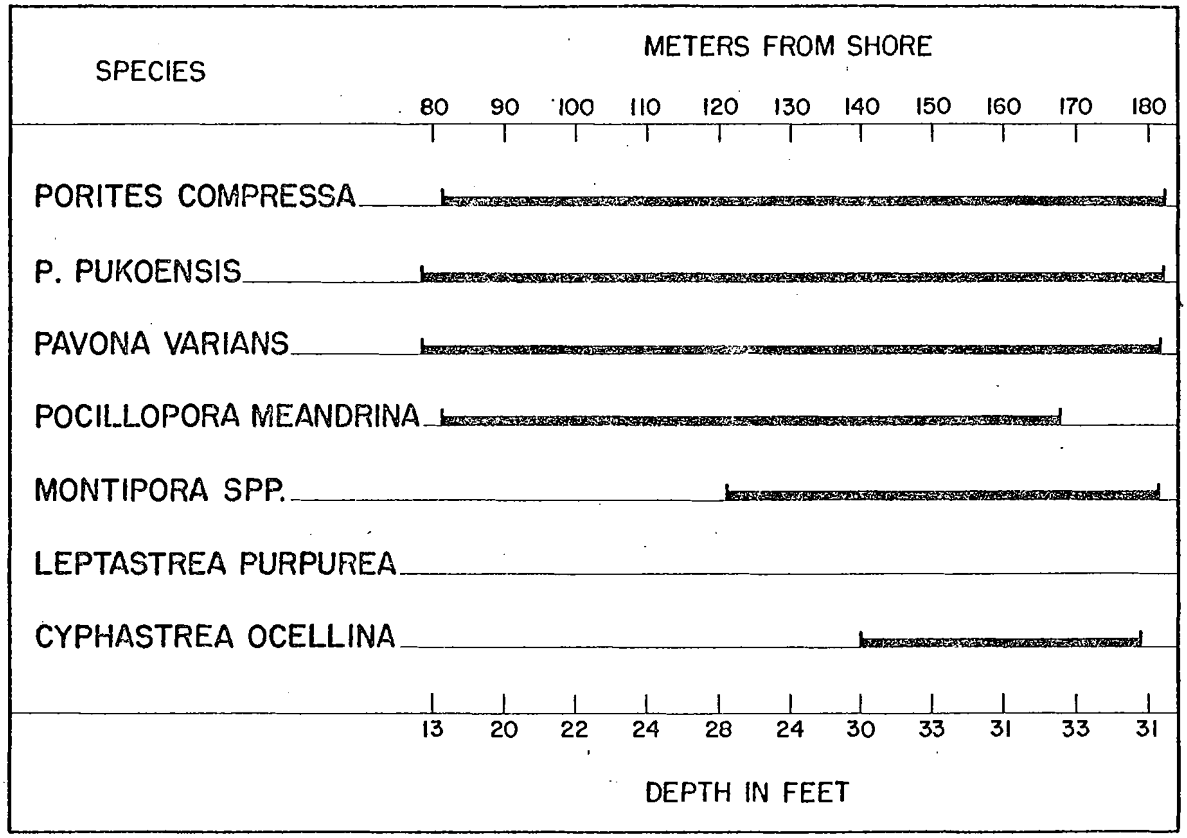

FIGURE 19. Coral composition on Transect 4, Honaunau Bay.

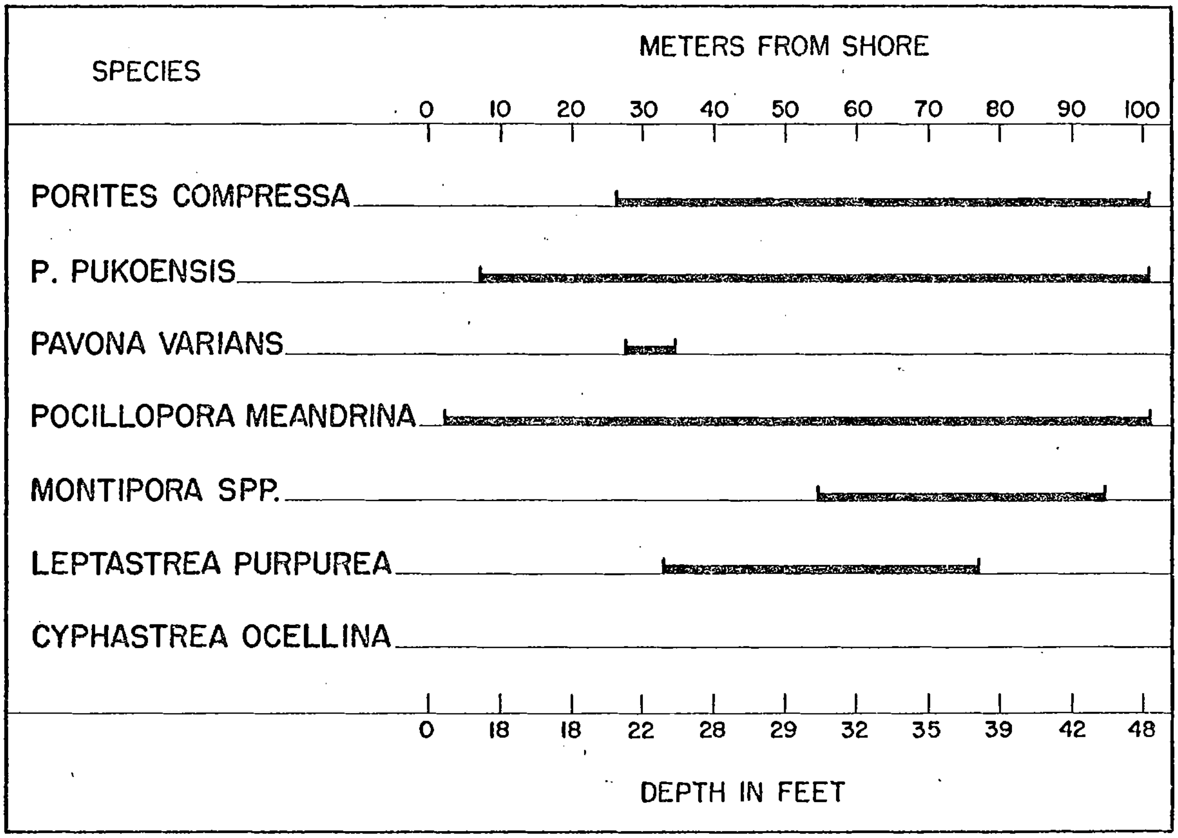

FIGURE 20. Coral composition on Transect 5, Alahaka Bay.

the Kona Coast include *Pocillopora damicornis*, *Psammocora stellata*, *Leptoseris hawaiiensis*, *Pavona explanata* and *P. minuta*.

TABLE 5. Absolute and relative abundance of corals in Honaunau Bay and Alahaka Bay.

	Honaunau Bay (4 transect average)		Alahaka Bay (1 transect)	
Coral species	% cover	% of coral cover	% cover	% of coral cover
PORITES PUKOENSIS	34.64	51.15	18.54	54.72
P. COMPRESSA	27.54	40.66	12.90	38.07
PAVONA VARIANS	3.60	5.31	--	--
LEPTASTREA PURPUREA	0.68	1.00	--	--
POCILLOPORA MEANDRINA	0.50	0.73	1.61	4.75
MONTIPORA SPP.	0.50	0.73	0.80	2.36
CYPHASTREA OCELLINA	<0.50	<0.50	--	--
% Coral Cover	67.72		33.88	

Pu'uhonua o Honaunau NHP Library

Discussion

1. General features of the coral community in Honaunau Bay and Alahaka Bay.

The coral community in these bays, although spectacular, is not very diverse. Indices of species diversity were computed (after Shannon & Weaver, 1949) for both bays. These were 0.846 for Honaunau Bay and 0.876 for Alahaka Bay and indicate relatively low species diversity. The indices of diversity are roughly the same even though the percentage total cover at Honaunau Bay is roughly twice that of Alahaka Bay. Table 5 also indicates that the relative composition of the two bays is roughly the same. In both cases, roughly 92 per cent of the total coral cover is attributable to the two dominant species of *Porites*.

2. Vertical zonation.

It is evident (Fig. 21) that the dominant species of *Porites* occupy somewhat different though overlapping habitats. *Porites pukoensis* reaches peak density between 5 and 20 feet while *P. compressa* reaches maximum density in depths greater than 20 feet. This is reasonable when the morphology of the two species is considered. The relatively fragile branches of *P. compressa* are easily broken in the surge characteristic of shallow water. However, branching increases the surface to volume ratio and since food catching ability should be related to exposed surface in corals, one might expect *P. compressa* to outcompete *P. pukoensis* at depths where surge is no longer important.

Abundance of *Pavona varians* follows that of *Porites compressa* very closely. *Pavona varians* is usually found encrusting dead bases of *Porites compressa*. Therefore the apparent correlation in abundances of the two species is not fortuitous.

Pocillopora meandrina is common in shallow water around the edge of the bays. Since all transects in this study ran directly offshore, however, the abundance of *P. meandrina* was underestimated. Its presence in the surge zone suggests that this species is tolerant to relatively harsh, unstable ecological conditions. Though it is a branching form, it is not broken by moderate surge and thus can occupy a habitat unavailable to *Porites compressa*.

The genus *Montipora* in Honaunau Bay is essentially restricted to deep water. It does not form a significant portion of the coral cover in depths less than 25 feet and increased in importance rapidly with depth. However, specimens were collected at a depth of four feet at Keone-eli cove in Honaunau Bay.

Distribution of total coral cover with depth (Fig. 22) is at a minimum in the surge zone and reaches peak cover between 15 feet and 25 feet. It then slowly decreases with increasing depth. The coral is probably limited by wave action near shore and perhaps by decreasing light penetration with increasing depth in deeper water.

3. Coral sensitivity to environmental conditions.

Within Honaunau Bay considerable variation in the percentage

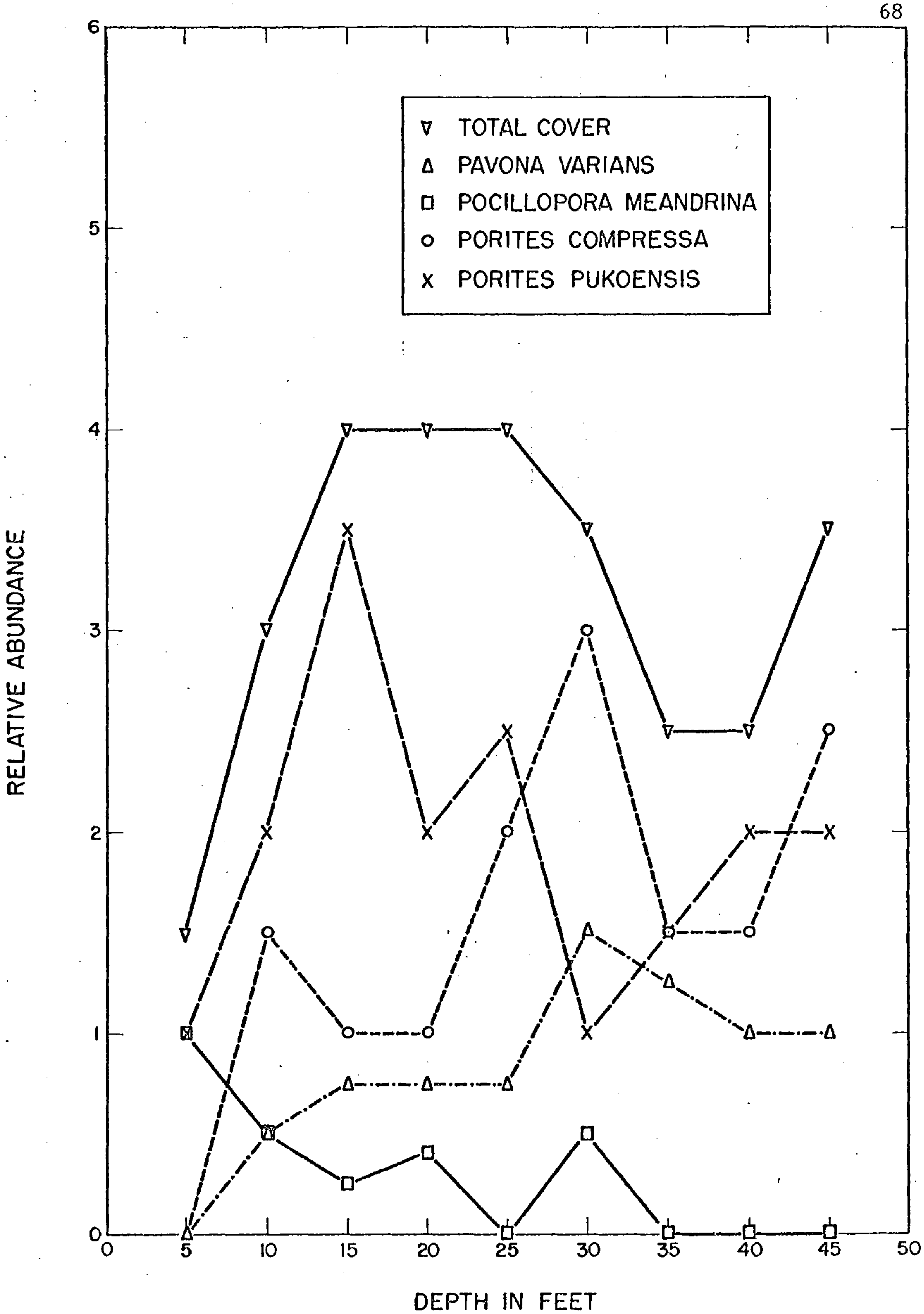

FIGURE 21. Composition of major coral species in Honaunau Bay as a function of depth.

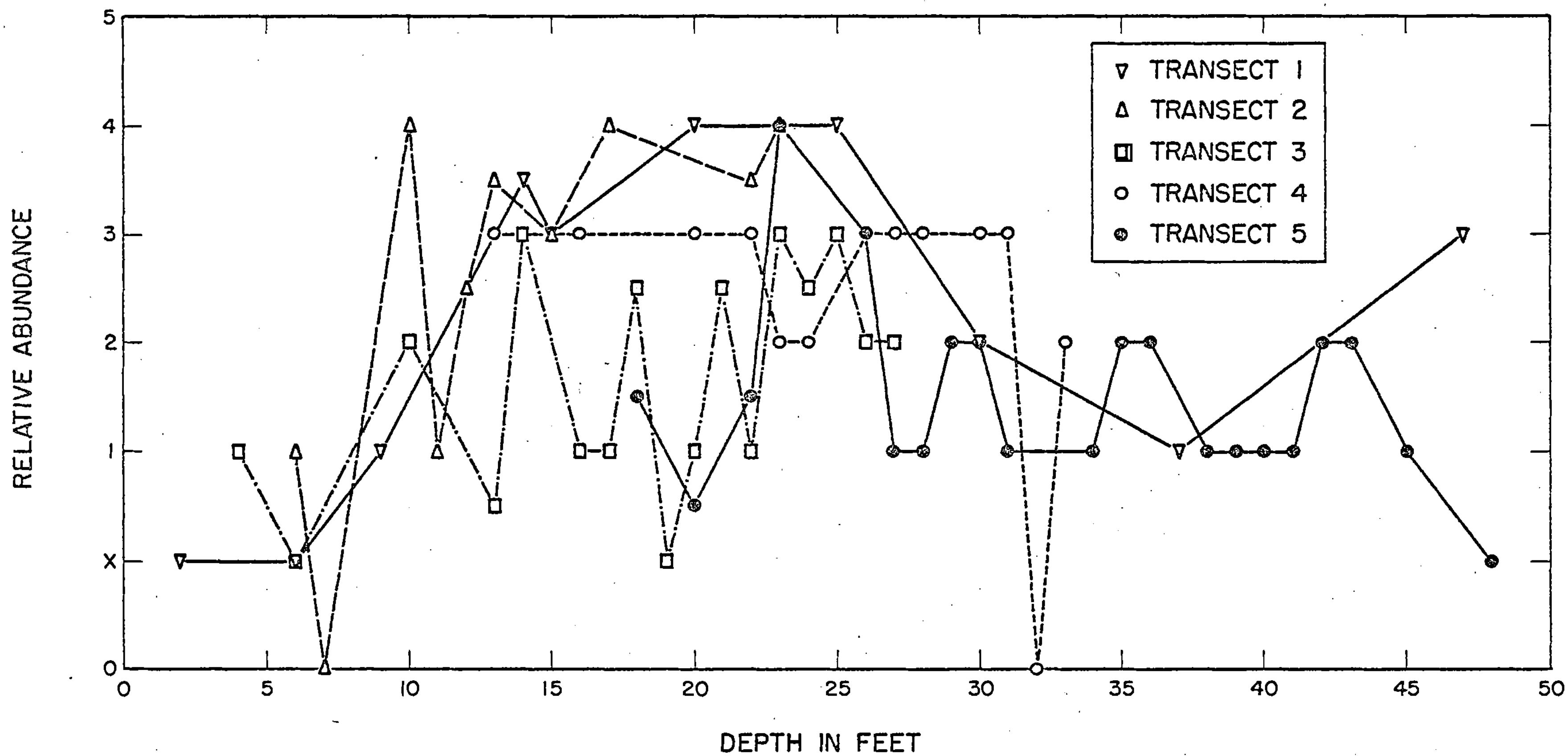

FIGURE 22. Total coral cover as a function of depth on Transects 1 through 4 at Honaunau Bay and Transect 5 at Alahaka Bay. "X" indicates coral was absent at the quadrat corners but present within the quadrat; "4" indicates coral was present at all four corners of the quadrat. The species composition is presented on Table 5.

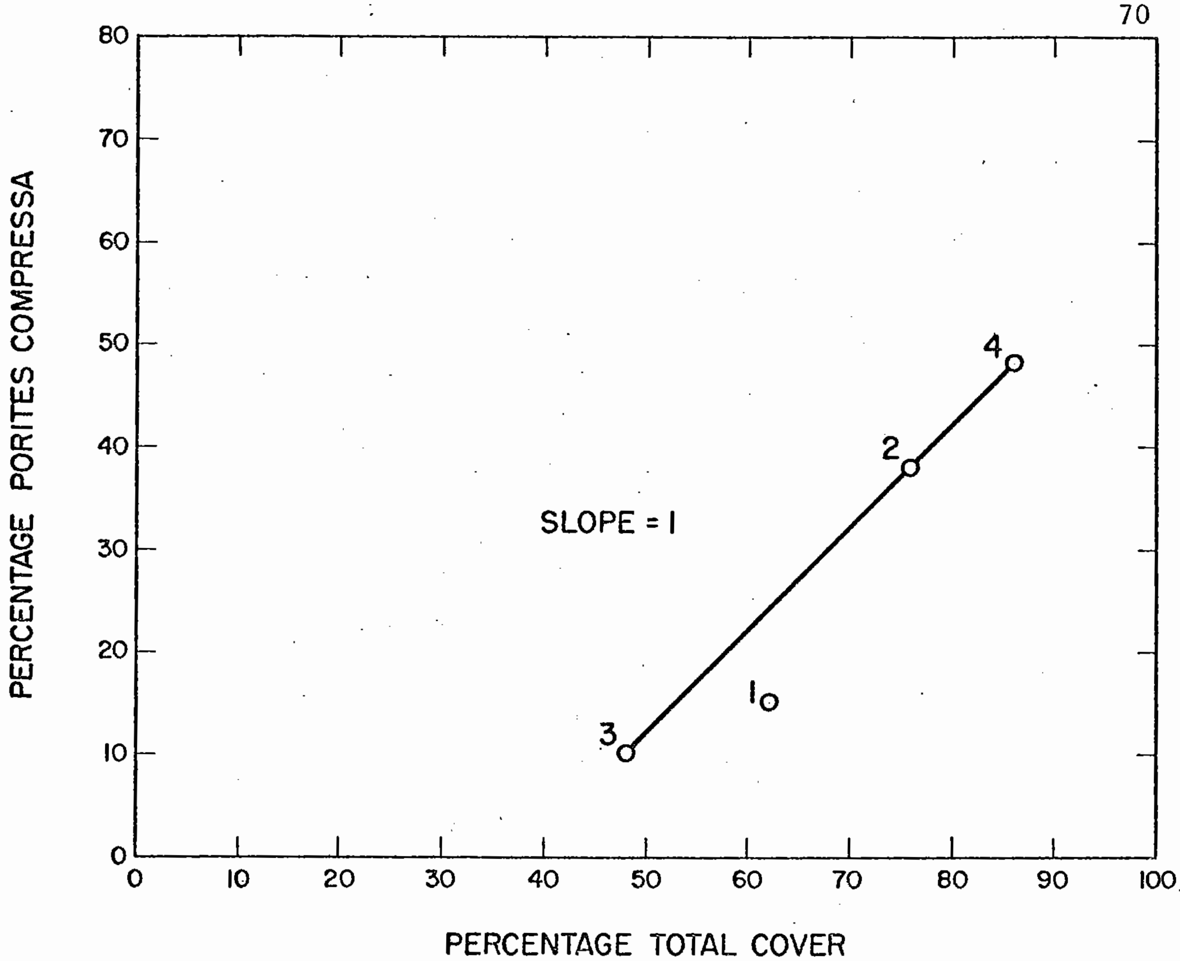

FIGURE 23. Coral cover in Honaunau Bay expressed as percentage cover by Porites compressa plotted against percentage total cover. The numbers are transect numbers, arranged on Figure 22, and the values represent mean cover on the entire transect.

total coral cover existed between transects. A plot of percentage cover of Porites compressa against percentage total coral cover (Fig. 23) yields a straight line with a slope very close to 1. This indicates that most variations in total coral cover within the bay are due to variations in cover of Porites compressa alone. If this is true, then the percentage cover of Porites pukoensis must remain essentially constant since these two species from the bulk of the coral community. This suggests that P. compressa is sensitive to local variations in ecological conditions within the bay while P. pukoensis and other species are more probably relatively insensitive to such variations.

The region of Keone-eli cove is contaminated by seepage from two cesspools a short distance from the sandy shoreline. In order to compare the biota exposed to this condition to biota in cleaner water, Transect 3 was established along the channel leading from the cove into the bay proper, and Transect 2 established (Fig. 12) just north in waters more typical of the bay. The reason Transect 3 lay at the entrance to Keone-eli and not within the contaminated cove itself is that there are no comparable cleaner areas within Honaunau Bay.

Data taken on the shoreward 60 meters of Transects 2 and 3 were contrasted. Contamination along much of this section of Transect 3 had been previously noted by the paucity of fish, turbidity of the water and by the presence of dead and encrusted coral.

There were 16 quadrat samples made along this section of each transect. On Transect 2 depths range from six to 17 feet with three quadrats under a depth of 10 feet and one over 15 feet. On Transect 3 depths range from four to 21 feet with two quadrats under 10 feet and eight over 15 feet. Transect 3 hence lies in slightly deeper water.

There were no significant differences in urchin populations along this section of the two transects, but the frequency of two coral species showed marked differences. Porites compressa was noted up to 17 feet on Transect 3 and was present three times on the 16 quadrats. On Transect 2 it was noted up to 10 feet and was present 17 times. Pavona varians, on the other hand, was present eight times on Transect 3 and only twice on Transect 2.

It is noted above that of the Honaunau corals, Porites compressa is probably the most sensitive to enviromental conditions. Since it is a deeper-water species, its far greater abundance on Transect 2, the shallower but cleaner transect, is indeed curious. It is noted above that Porites compressa and Pavona varians share similar distributions as the latter species encrusts dead areas of the former. On Transect 3, however, the relationship is inverse. The obvious explanation of these inconsistencies is that much dead Porites compressa is present on Transect 3, but is so totally abraded and encrusted by Pavona that it was not identified as such.

Porites compressa, then, used to be far more common in this section of Honaunau Bay than it is today. The worn bases are still present and are abundantly encrusted with Pavona. As no other explanation is available, presumably the passing of finger coral was brought about by pollution factors such as increased levels of phosphorus in the water.

4. Urchin-coral relationships.

Tests were run to determine if sea urchin abundance was related to the abundance of any single coral species or combination of coral species, to coral diversity or to total coral cover. No apparent correlations exist. Thus urchin abundance appears to be independent of coral abundance and the factors which regulate the abundance of the two types of organisms are probably not the same.

Chapter 9

MARINE MOLLUSKS

Approximately 120 species of marine and brackish water mollusks are here recorded (Table 6) from the environs of Honaunau Bay, Hawaii. The assemblages are described below in terms of five general habitat types: high shoreline (or supralittoral), exposed intertidal cliffs and benches, tidepools, brackish water areas and subtidal reaches, and are compared with the molluscan biota of a neighboring Kona Coast area and with that of a topographically similar region at Poipu, Kauai.

This survey of the marine molluscan fauna of Honaunau is based on a three-day study of the area conducted in April, 1969. Some observations from an earlier survey of the bay (Kay, 1957) are incorporated in the report to increase its scope. The April, 1969, survey was limited to examination and analysis of shoreline habitats; subtidal observations are minimal because an extensive survey of the subtidal reaches of the bay is possible only with the participation of a team of divers

The high shoreline

The dominant mollusks of the high shoreline or supralittoral region at Honaunau Bay are, as is characteristic of this region throughout the islands, the littorines, *Littorina picta* and *L. pintado*. Littorines are to be found in abundance on the bluffs of the north rim of the bay, on the sea-level basalt platforms fringing the eastern half of the bay, and on the extensive basalt shelf, Puuhonua Point, which forms the southwestern margin of the City of Refuge. They occur above the normal reaches of tides and waves but within reach of spray.

In addition to the dominant littorines noted above, two unusual populations of high shoreline mollusks were also seen at Honaunau, both on the basalt substrate fringing the shore at the mouth of the inlet, Kapuwa'i. Beneath the stone wall at the southeastern rim is a colony of two species of marine pulmonates, *Melampus* sp. and *Laemondonta bronni*. Although marine pulmonates are of fairly common occurrence in high shoreline boulder and rubble areas along all Hawaiian coasts, this colony is

TABLE 6. A check list of marine mollusks recorded from Honaunau and Kealakekua Bays, Hawaii, and Poipu, Kauai.

GASTROPODS	Honaunau Bay	Kealakekua Bay	Poipu, Kauai
Diodora granifera	x	x	x
Tugali oblonga		x	
Cellana exarata	x		x
Cellana sandwichensis	x	x	x
Cellana talcosa	x	x	x
Euchelus gemmatus	x	x	x
Trochus histrio	x	x	x
Gibbula marmorea	x	x	x
Thalotia rubra	x	x	x
Thalotia subangulata			x
Phasianella variabilis	x	x	x
*[1]Leptothyra rubricincta	x	x	x
*[2]Leptothyra verruca			x
Synaptocochlea concinna	x		x
Turbo argyrostoma	x	x	x
Nerita picea	x	x	x
Nerita polita		x	x
Theodoxus neglectus	x	x	x
*[3]Theodoxus cariosa	x		
Littorina picta	x	x	x
Littorina pintado	x	x	x

TABLE 6 (continued)

GASTROPODS	Honaunau Bay	Kealakekua Bay	Poipu, Kauai
*4 Littorina undulata	x		
Peasiella tantilla	x	x	x
Planaxis labiosa	x	x	x
Phenacolepas sp.	x	x	x
*5 Barleeia sp.	x		x
Rissoina ambigua	x	x	x
Rissoina gracilis	x		x
Rissoina miltozona	x	x	x
Rissoina triticea	x		x
Rissoina turricula	x	x	x
Parashiela sp.	x		x
Merelina sp.		x	x
Zebina tridentata		x	x
Cyclostremiscus minutissimus	x		x
Vitrinellid sp. 1	x		
Vitrinellid sp. 2	x		
Risoella sp.	x		x
Assiminea sp.		x	x
Caecum sepimentum	x		x
*6 Bittium parcum	x		x
Bittium zebrum	x	x	x
Cerithium atromarginatum	x	x	x
Cerithium interstriatum	x		x
Cerithium nesioticum	x	x	x

TABLE 6 (continued)

GASTROPODS	Honaunau Bay	Kealakekua Bay	Poipu, Kauai
*7 Cerithium pharos		x	
*7 Cerithium granifera		x	
*7 Cerithium columna		x	
Obtortio sp.	x		x
Scaliola sp.	x		x
Plesiotrochus souverbianus		x	x
Cerithiopsis spp.	x		x
Vanikoro sp.		x	x
Fossarus sp.	x	x	x
Modulus tectum		x	x
Dendropoma sp.			x
Serpulorbis sp.	x	x	x
Vermetus sp.		x	x
Triphora spp.	x(2)	x(10)	x
Balcis sp.		x	x
Leostraca metcalfei		x	x
Mucronalia nitidula	x		x
Stilifer mittrei		x	x
Epitonium spp.		x	
Strombus maculatus	x		x
Hipponix australis	x	x	x
Hipponix grayanus		x	x
Hipponix foliaceus	x	x	x
Hipponix pilosus	x	x	x

TABLE 6 (continued)

GASTROPODS	Honaunau Bay	Kealakekua Bay	Poipu, Kauai
Cheilea equistris		x	
Crucibulum spinosum		x	
Erato sandwichensis		x	x
Cypraea fimbriata	x	x	x
Cypraea mauiensis		x	
Cypraea moneta	x		x
Cypraea poraria		x	x
Cypraea teres		x	x
Cypraea caputserpentis	x	x	x
Cypraea maculifera	x	x	x
Cypraea mauritiana	x	x	x
Cypraea tigris		x	x
Trivia insecta		x	x
Trivia edgari		x	x
Trivia rosacea		x	x
Charonia tritonis		x	x
Cymatium nicobaricum	x	x	x
Cymatium pileare	x	x	x
Bursa bufonia	x		
Cassis cornuta		x	x
Heliacus implexa		x	x
Polinices sp.		x	x
Natica marochiensis	x	x	x
Kogomea sandwichensis	x	x	x
Volvarina sp.			x

TABLE 6 (continued)

GASTROPODS	Honaunau Bay	Kealakekua Bay	Poipu, Kauai
Aspella sp.	x	x	x
Coralliophila sp.		x	x
Drupa morum	x		x
Drupa ricina	x	x	x
Drupa rubusidaeus		x	x
*8 Maculotriton serriale			x
Morula brunneolabrum	x		
Morula granulata	x	x	x
Morula ochrostoma	x	x	x
Morula uva	x		x
Provexillum fusconigra	x		x
Provexillum vexilla	x		x
Nucella harpa	x	x	x
Rhizochilus madreporarum	x		
Thais intermedia		x	
Engina iodosia			x
Euplica varians	x	x	x
*9 Mitrella fusiformis	x	x	x
*9 Mitrella margarita	x	x	x
Seminella varia	x		x
Columbellidae		(4 sp.)	
Peristernia chlorostoma	x		x
Latirus nodatus		x	
Buccinidae		(4 sp.)	
Turridae		(23 sp.)	

TABLE 6 (continued)

GASTROPODS	Honaunau Bay	Kealakekua Bay	Poipu, Kauai
Carinapex minutissima	x		x
Daphnella interrupta			x
Iredalea exilis	x		x
Kermia harenula	x		x
Kermia pumila	x		x
Daphnella producta	x		x
Macteola segesta		x	
Mitra cancellarioides	x		
Mitra cucumerina	x		x
Mitra litterata	x	x	x
Mitra spp.		(3 sp.)	(3 sp.)
Conus abbreviatus	x	x	x
Conus catas	x		x
Conus chaldaeus	x	x	x
Conus distans	x		x
Conus flavidus	x		x
Conus lividus	x	x	x
Conus sponsalis	x	x	x
Conus ebraeus	x	x	x
Conus imperialis	x		
Conus miles		x	
*10 Conus pulicarius		x	
Conus rattus	x		x
*11 Terebra affinis		x	
*11 Terebra argus		x	

TABLE 6 (continued)

GASTROPODS	Honaunau Bay	Kealakekua Bay	Poipu, Kauai
*[11] Terebra felina		x	
*[11] Terebra guttata		x	
*[11] Terebra inconstans		x	
*[11] Terebra hectica		x	
*[11] Terebra penicillata		x	
*[11] Terebra strigilata		x	
Siphonaria normalis	x	x	x
Melampus sp.	x	x	x
Pedipes sp.	x	x	x
Laemodonta bronni	x	x	
Atys sp.		x	
Atys semistriata		x	x
Haminea crocata	x		x
Haminea simillima	x		
Bullaria adamsi	x		x
Bullina scabra		x	x
Julia exquisita		x	x
Pyramidellid sp.			x
*[12] Otopleura mitralis		x	
*[12] Pupa thaanumi		x	
*[12] Pyramidella sulcata		x	
Umbraculum		x	x
Smaragdinella calyclulata	x	x	x
Aplysia parvula		x	x
Dolabrifera dolabrifera	x	x	x

TABLE 6 (continued)

GASTROPODS	Honaunau Bay	Kealakekua Bay	Poipu, Kauai
Stylocheilus longicaudus	x		x
Elysia reticulata		x	x
Glossodoris lineata		x	x
Onchidium sp.		x	x
Dendrodoris nigra		x	x
Hexabranchus sp.	x		x
Hydatina amplustre	x		x
Micromelo guamensis	x		x
BIVALVES			
Acar plicata		x	x
Hemicardium mundum		x	x
Nesobornia ovata	x	x	x
Periglypta reticulata	x	x	x
Ctena bella	x	x	x
Spondylus sp.	x	x	x
Ostrea hanleyana	x	x	x
Isognomon perna	x	x	x
Isognomon californicum	x	x	
*13 Pecten sp.		x	
*13 Pinguitellina robusta		x	
*13 Tellina spp.		x	
*13 Macoma sp.		x	
*13 Angulus sp.		x	
Hormomya crebristriatus	x	x	x

TABLE 6 (continued)

BIVALVES	Honaunau Bay	Kealakekua Bay	Poipu, Kauai
Pinna muricata	x		x
Chama iostoma	x	x	x
Pinctada radiata	x	x	x
Ervilia sp.	x		x
Anisodonta angulata	x		x
Arcinella sp.	x		
AMPHINEURA			
Ischnochiton viridis	x		x

Notes:

*1. Leptothyra rubricincta is very common at both Honaunau and Kealakekua Bays but uncommon at Poipu, Kauai.

*2. Leptothyra verruca is one of the dominant trochids at Poipu, Kauai but is apparently absent at both Honaunau and Kealakekua.

*3. Theodoxus cariosa occurs only in still brackish and freshwaters.

*4. Littorina undulata is one of the two dominant littorines in the Central Pacific but only rarely found in the Hawaiian Islands.

*5. Barleeia sp. forms 31% of the algal mat in Padina-dominated outer seaward tidepools at Honaunau and 41% of the mat in similarly placed, pools at Poipu, Kauai.

*6. Bittium parcum forms only 13% to 27% of the mollusks in the algal mat of seaward tidepools at Honaunau, Hawaii but up to 40% of the mat in similar tidepools on Kauai.

*7. Cerithium pharos, C. granifera, and C. columna are sand-dwelling mollusks, usually found at depths of 10 feet or more.

*8. The absence of the muricid Maculotriton serriale both at Honaunau and Kealakekua is interesting; it is a very common species at Poipu, Kauai.

*9. Mitrella margarita is apparently the dominant columbellid at both Honaunau and Kealakekua Bays while M. fusiformis is present but uncommon; the opposite situation holds at Poipu, Kauai: in recent collections from there more than 50 M. fusiformis were counted, 3 M. margarita.

*10. Conus pulicarius is a sand-dwelling cone.

*11. Terebra spp. are all sand-dwellers and might be expected to be absent from the Honaunau and Poipu collections which are chiefly from the tidepool systems.

*12. Otopleura mitralis, Pupa thaanumi, and Pyramidella sulcata are sand-dwellers which occur in rather deep water (10 feet or more).

*13. Pecten sp. Pinguitellina robusta, Tellina spp., Macoma, and Angulus are all sand dwellers.

unusual in that its members intermingle with the littorines and the usually more seaward-occurring pipipi or nerite, Nerita picea. In a restricted area just beneath the entrance to the Palace Grounds, in the southernmost corner of the inlet, a very small colony (perhaps not more than ten animals) of the Central Pacific littorine, Littorina undulata, was found. This species has previously been recorded in the islands only from two or three specimens collected on Oahu and from a single colony which lives in the keawe trees rimming Olowalu Bay, Maui.

Intertidal cliffs and benches

Seaward of the supratidal region (Fig. 24, Nerita picea), on the cliffs in the Miana Point area and on the sea-level basalt platforms which fringe most of the bay to Puuhonua Point, the littorines are replaced by the black pipipi mentioned above, Nerita picea, and, in lesser abundance and with a somewhat spotty distribution, the pulmonate limpet Siphonaria normalis and the cephalaspid opisthobranch Smaragdinella calyculata. The opihis, Cellana exarata and C. sandwichensis, which are generally characteristic of the intertidal fringe throughout the islands occur in this habitat, too, but only ten or twelve specimens were noted, compared with densities as high as 68 per m^2 found at Kealakekua Bay in October, 1968. A large number of opihi shells is to be found in the waters at Kapuwa'i but these merely represent limpets brought from other areas of the Kona Coast and cleaned in the inlet.

At still lower levels of the shoreline (Fig. 24, Drupa-Conus), where dense algal turf covers the basalt benches and where there is usually considerable surf action, another assemblage of mollusks occurs: the mollusk-feeding muricids Morula granulata and Drupa ricina, the vermivorous muricid D. morum, the vermivorous cones, Conus sponsalis and C. lividus, and the omnivorous grazers Cypraea caputserpentis and C. maculifera. In the lower reaches of these surf-swept benches, and not usually visible to the collector from the surface during daylight hours but active at night during low tides, are the large opihi Cellana talcosa and the humpback cowry Cypraea mauritiana.

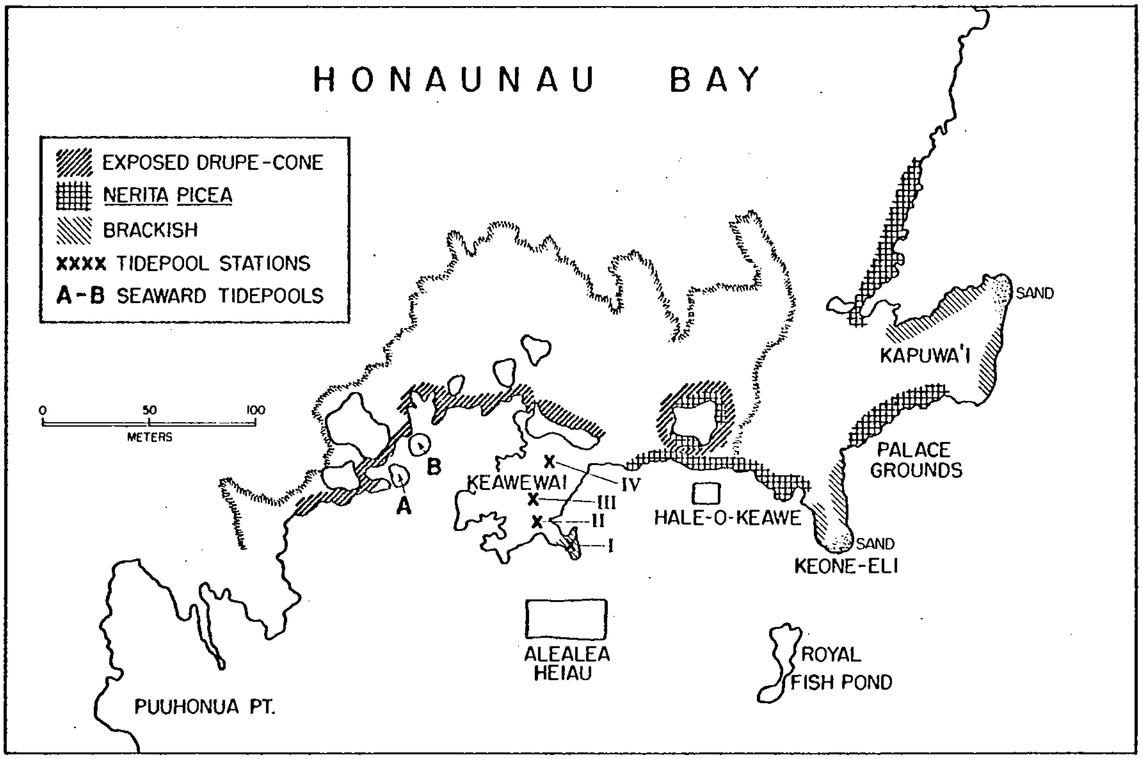

FIGURE 24. Honaunau Bay indicating shoreline habitats and associated mollusks and tidepool stations.

Tidepools

Tidepools have long fascinated biologists because of the variety of biota which may be found in them. The tidepools of Honaunau are of more general interest, however, for they harbor not only a diverse and colorful biota, but are easily accessible to the visitor. The tidepool system at Honaunau is, therefore, perhaps the most interesting and attractive feature of the shoreline, for the pools include (Table 7) a variety of types: brackish water and highly saline pools at the shoreward edge, more diversely inhabited pools in the middle reaches of the basalt benches and richly ornamented seaward pools.

The most extensively developed tidepool system at Honaunau is that formed by the arm of the bay which indents the lava shore southwest of Hale-o-Keawe, and called Keawewai (Fig. 24, I to IV, and Table 7). At its shoreward extent, near the Great Wall of the City of Refuge, the pool is characterized by a lens of freshwater; here only six molluscan species are found, four in abundance. The dominant mollusks are the black mussel, Isognomon californicum, which forms clusters around the edge of the pool, while on the rocky substrate within the pool are the small black euryhaline pipipi, Theodoxus neglectus, and a brown and white pipipi-like snail, Planaxis labiosus. The dense algal mat in this portion of the pool contains in addition several micromollusks, the smallest (0.5 mm in diameter), Risoella sp., is the dominant form, while the larger shells of Bittium parcum (2.0 mm) and Cerithium atromarginatum (12.0 mm) are also present. As the freshwater lens gradually disappears seaward, the algal mat and the molluscan population change in composition, with the mussel dropping out, the pipipis becoming less numerous, and Bittium parcum becoming dominant; nine other molluscan species are also found in the algal mat here. Toward the middle of the inlet (Fig. 24, III), where it widens out into a pool of considerable diameter, still another change occurs, both in the composition of the algal mat and the molluscan population with more molluscan species contributing to the species composition, although Bittium parcum remains dominant here, too. As the seaward edge of the pool is approached (Fig. 24, IV), the algal mat disappears and the substrate becomes one of loose rubble studded with sea urchins. Here some

TABLE 7. Distribution of mollusks in the tidepool systems. x = present; xxxx = abundant.

	KEAWEWAI				SEAWARD POOLS	
	I Brackish	II Upper algal mat	III Lower algal mat	IV Outer Reaches	A *Padina* Pool	B *Boodlea* Pool
Bittium parcum	xx	xxxx	xxxxx	xx	xxx	xx
Cerithium atromarginatum	x	x	xx	x	xxx	x
Risoella sp.	xxxxx	xxx	xx		x	x
Theodoxus neglectus	xxxxx	xx				
Isognomon californicum	xxxxx					
Planaxis labiosus	xxx					
Morula granulata		x	x	x	x	x
Isognomon perna		x	x	x	x	
Dolabrifera dolabrifera		x	x	xx		
Morula ochrostoma		x	x	x		
Mitrella fusiformis		x	x	x		
Ervilia sp.		x	x		x	
Cyclostremiscus minutissimus		x			xx	xx
Merelina sp.		x			x	x

TABLE 7 (continued)	I	II	III	IV	A	B
Pyramidellid sp.		x			x	x
Kogomea sandwichensis		x			x	
Parashiela sp.		x			x	
Provexillum fusconigra		x				
Epitonium sp.		x				
Conus ebraeus			x	xx	x	x
Rissoina ambigua			xx	xxx	xx	
Trochus histrio			x	x		
Rissoina triticea			x	x		
Haminea crocata			x		x	
Caecum sepimentum			x		x	
Triphora cingulifera			x		x	
Cerithium interstriatum			x			
Rissoina gracilis				x	x	x
Rissoina miltozona				x	x	x
Serpulorbis sp.				xx	xx	xx
Carinapex minutissiums				x	x	x

TABLE 7 (continued)

	I	II	III	IV	A	B
Stylocheius longicaudus				x	x	
Mitrella margarita				x	x	
Rissoina tridentata				x		
Hipponix spp.				x		
Vermetus sp.				x		
Cypraea fimbriata				x		
Euplica varians				x		
Seminella varia				x		
Cymatium nicobaricum				x		
Peristernia chlorostoma				x		
Morula brunneolabrum				x		
Morula ova				x		
Provexillum vexillum				x		
Mitra cancellaroioides				x		
Mitra cucumerina				x		
Kermia harenula				x		
Daphnella producta				x		

TABLE 7 (continued)

	I	II	III	IV	A	B
Acar plicata				x		
Ostrea hanleyana				x		
Arcinella sp.				x		
Nesobornia ovata				x		
Ischnochiton viridis				x		
Hiloa variabilis					x	xx
Chama iostoma					xx	xx
Conus catus					x	x
Conus flavidus					x	x
Conus lividus					x	x
Conus rattus					x	x
Conus sponsalis					x	x
Gibbula marmorea					x	
Kermia pumila					x	
Diodora granifera					x	
Hormomya crebristriatus					x	
Cerithium nesioticum					x	

TABLE 7 (continued)	I	II	III	IV	A	B
Rissoina turricula					x	
Vitrinellid sp. 1					x	
Vitrinellid sp. 2					x	
Barleeia spp.						xxx
Obtortio sp.						x
Scaliola sp.						x
Cerithiopsis sp.						x

22 species of mollusks are found, almost all of them cryptofaunal and occurring beneath the rubble; no one species appears to be dominant here.

The tidepools at the outer edge of Puuhonua Point (Fig. 24, A & B) again present a different picture; they are subject to considerable surf action daily. They, too, have substrates of algal mat, but here are found some of the more picturesque and larger mollusks. The worm shell Serpulorbis and the sedentary bivalve Chama pave the hard substrate among clumps of algae. In the algal turf are the vermivorous cones, Conus ebraeus, Conus sponsalis, and C. lividus, the mollusk-feeding tritons Cymatium nicobaricum and C. pileare, and the molluscivorous muricids Morula granulata and M. ochrostoma. Hidden in cracks and crevices are the cowries, the commonly found snakehead, Cypraea caputserpentis, and the less commonly occurring C. isabella and C. helvola. And finally, some 20 species of micromollusks are to be found in the algal mat and its associated sand pockets.

Brackishwater assemblages

Four brackish water assemblages of mollusks were noted at Honaunau (Fig. 24, Brackish); one has been discussed, that at the eastern end of the inlet, Keawewai. At Kapuwa'i dense beds of the black mussel, Isognomon californicum, rim the hard substrate which fringes the northern, eastern and southern rims of the inlet, while the small pipipi, Theodoxus neglectus, extends both higher and lower than does the fringing mussel. Occasional specimens of Planaxic labiosus were also found here. The assemblage at Keone-eli appears to be slightly more diverse in that the muricid Morula granulata was found here, apparently feeding in the mussel beds. Its presence may indicate a slightly less brackish condition than occurs in Kapuwa'i.

Isognomon californicum, Theodoxus neglectus and Planaxis labiosus are apparently euryhaline, for all three species occur in more saline waters throughout the islands; however, they occur in greatest abundance in waters which are at least slightly brackish, and because all three appear to occur together, are considered indicative of brackish waters when they appear in dense masses.

The Royal Fishpond, within the park, is habitat for still another brackish water mollusk, this one limited in its distribution to brackish and fresh water: *Theodoxus cariosus*, the humped gray-black nerite. It is distinguished from two of its relatives not only by its characteristically humped shell, but also by its habit in still waters; the granulated black nerite, *Theodoxus granulata* (as at Sacred Falls, Oahu), occurs in swift flowing streams, while the smooth, olive, winged nerite, *Theodoxus vespertina*, is to be found in slow-flowing rivers (as in the Hanalei River, Kauai).

Subtidal bay fauna

The subtidal fauna of the bay is apparently similar to that found in Kealakekua Bay, although there may be a somewhat less diverse fauna associated with a less diverse coral biota. The common larger and more spectacular mollusks such as the helmet shell, *Cassis cornuta*, the tiger cowry, *Cypraea tigris*, and the triton, *Charonia tritonis*, should all be found at depths of 10 feet or more in the bay, and sand pockets should harbor a number of species of auger shells, *Terebra* spp., and bivalves such as tellinids.

Discussion

The molluscan assemblages described from Honaunau Bay are perhaps most usefully discussed in terms of comparisons with those of 1) a neighboring area of the Kona Coast, *e.g.*, Kealakekua Bay, and 2) a topographically similar area on another of the Hawaiian islands, *e.g.*, Poipu, Kauai.

Approximately 120 species of marine and brackish water mollusks are now recorded for Honaunau Bay; some 160 species were recorded (Doty, 1968) during a survey made in October, 1968, from Kealakekua Bay, which lies just north of Honaunau. The greater number of species found at Kealakekua is apparently at least partially due to the types of areas collected: the subtidal reaches of Kealakekua were extensively sampled whereas those at Honaunau were not studied in any detail. When the lists from the two areas are compared, it is immediately noticeable that of the 50-odd species found at Kealakekua but not at Honaunau, about half are deep-dwelling (10 to 30 feet), sand dwellers (Cassis, 3 species of Cerithium, 8 species of Terebra, a number of bivalves, etc.) and another group are deep-occurring epifaunal species (Latirus nodatus, Cypraea tigris, Tugali oblonga, Conus miles). At least some of these deep-occurring species should be found at Honaunau if the subtidal reaches of the bay are surveyed.

Differences in topography and other physical factors apparently also account for the differences in the lists of species. At Kealakekua Bay there are more extensive high cliff areas than are found at Honaunau, providing habitats for some apparently exclusively "cliff-dwelling" mollusks (Thais intermedia), and the tidepool systems are much more restricted in development than at Honaunau, where there is little development of dense algal turf either in tidepools or on exposed sea-level benches and the brackish water areas are more limited in scope. Comparison of the lists of species occurring at Honaunau and Kealakekua again demonstrates a difference: of the 45 species found at Honaunau but not at Kealakekua, 23 are forms associated with algal mat either in tidepools or exposed sea-level benches, and, of course, the non-flowing brackish water in the Royal Fishpond offers a habitat not found at Kealakekua Bay but where Theodoxus cariosus is found at Honaunau.

One similarity and an additional difference between the molluscan biotas of Honaunau and Kealakekua should be pointed out. In terms of percentage composition of species, the proportion of gastropods to bivalves (89:11) is the same for Honaunau and Kealakekua, and is in general higher in terms of gastropods than it is for the Hawaiian Islands as a whole (82:18), and considerably higher than for Kaneohe Bay, Oahu (80:20). Finally, the brackishwater assemblages at Honaunau are much more densely developed than they are at Kealakekua Bay: while at Kealakekua the assemblages are noticeable, at Honaunau the brackishwater mussel forms thick beds and the pipipi (Theodoxus neglectus) also appears to be present in far greater numbers in brackishwater areas than in similar areas at Kealakekua.

Comparison of the list of mollusks occurring at Honaunau with that found at Poipu, Kauai, a basalt projection with a tidepool system of almost the same area as that at Honaunau, shows an almost identical list of species. This suggests that assemblages of about 120 species are characteristic of all basalt shorelines with extensive pool systems in the islands. Despite the similarity between the two lists, some differences should be pointed out.

1) The conspicuous brackishwater assemblages found at Honaunau do not occur at Poipu, and although the black pipipi Theodoxus neglectus is present, it occurs in more highly saline waters.

2) There are differences in species abundance and representation in three families: the Trochidae or top shells, the Columbellidae or dove shells and the Thaisidae. At Honaunau the dominant micro-trochid is Leptothyra rubricincta; it is present at Poipu but only a few are found and the dominant small trochid is, instead, L. verruca, which was not found at either Honaunau or Kealakekua. The dominant columbellid at Honaunau (and which is also apparently very common in the coral heads at Kealakekua) is Mitrella margarita while M. fusiformis is present but rarely; at Poipu the reverse is characteristic: in a recent survey of the tidepool system more than 50 specimens of M. fusiformis were recorded, three of M. margarita. And, finally, Maculotriton serriale, a very common molluscivorous muricid at Poipu,was not found either at Honaunau or Kealakekua Bays. These differences perhaps reflect differences in insular colonization rather than differences in topography or other physical or biotic factors.

Chapter 10

SEA URCHINS

As part of a study of the ecology of Honaunau Bay, the abundance and distribution of sea urchins was measured. Five 100-meter transects (Fig. 25) were established, four at Honaunau and one in nearby Alahaka Bay. A one-meter-square quadrat was placed by a SCUBA-diver along the transect at regular intervals (usually every 2 or 3 meters), the urchins within counted, and the depth noted with a wrist depth gauge. Coral data were collected at the same time (presented in Chapter 8). A similar method of collecting data was employed by Dr. Thomas Ebert in part of a recent study (Doty, 1968) of Kealakekau Bay, and furnishes a convenient comparison.

Sea urchins were important to ancient Hawaiians. Urchin test and spine fragments comprise a sizable percentage of the total material found in some Hawaiian archaeological sites. Heterocentrotus spines were used as files to make fishhooks, and at least one was carved into an image (T. Stell Newman, personal communication). Bryan (1915) reports that Echinometra was eaten by the natives, and Echinothrix and Diadema were both highly esteemed as food. Doubtless other urchins were also eaten. Echinothrix is consumed today by the local populace, but information was not sought on the extent of this practice.

The urchin species observed in the present survey were Heterocentrotus mammillatus, Echinometra mathaei, Echinometra oblonga, Echinothrix diadema, Echinothrix calamaris, Tripneustes gratilla, Colobocentrotus atratus, Echinostrephus aciculatus, Eucidaris metularia and Diadema paucispinum. The last three were only rarely observed, and Colobocentrotus was found only in the surf zone. Here, however, it was sometimes very abundant, particularly in bluff-like, exposed areas.

Depth distribution of the various urchins (Fig. 26) varied little between transects, and hence the average for all four Honaunau transects were accomodated onto a single graph. The average densities at various depths of the urchins Echinometra (Fig. 25) and Heterocentrotus (Fig. 27) were plotted separately to facilitate comparing the present survey with

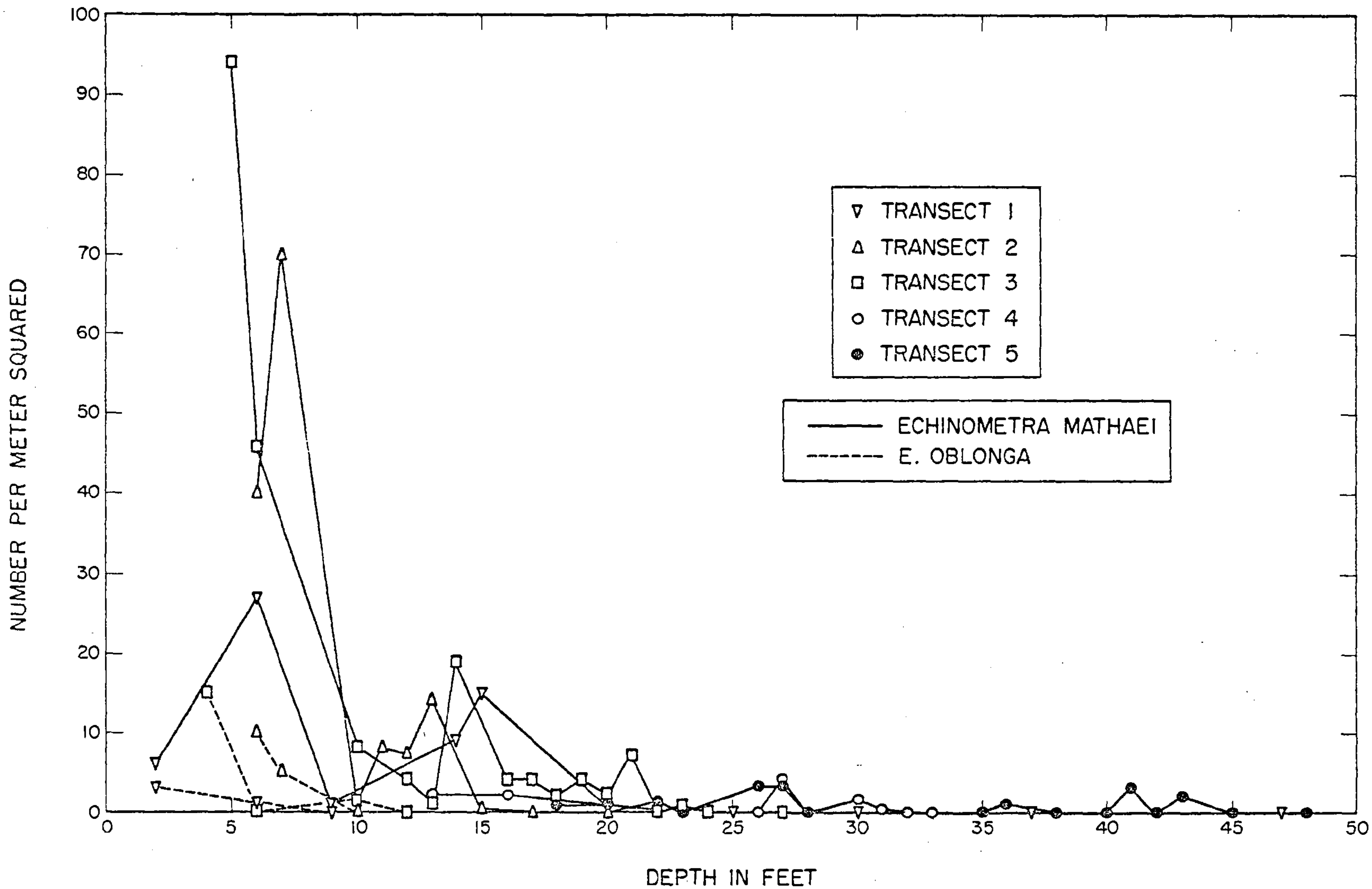

FIGURE 25. Density of the urchins, Echinormetra mathaei and E. oblonga, as a function of depth at selected regions of Honaunau Bay and Alahaka Bay. Transects 1 through 4 are in Honaunau Bay, Transect 5 in Alahaka Bay.

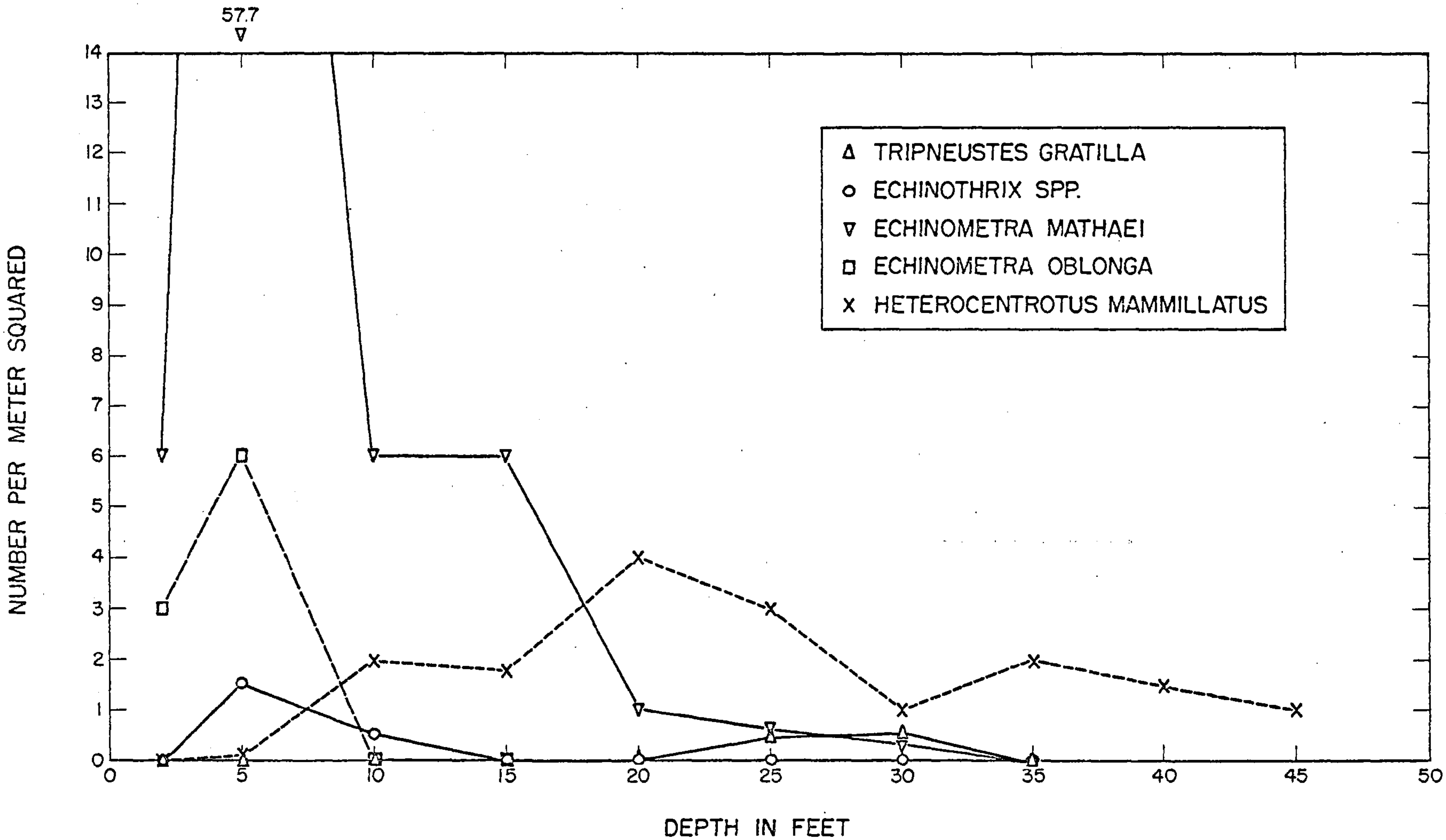

FIGURE 26. Urchin density as a function of depth for major species at Honaunau Bay.

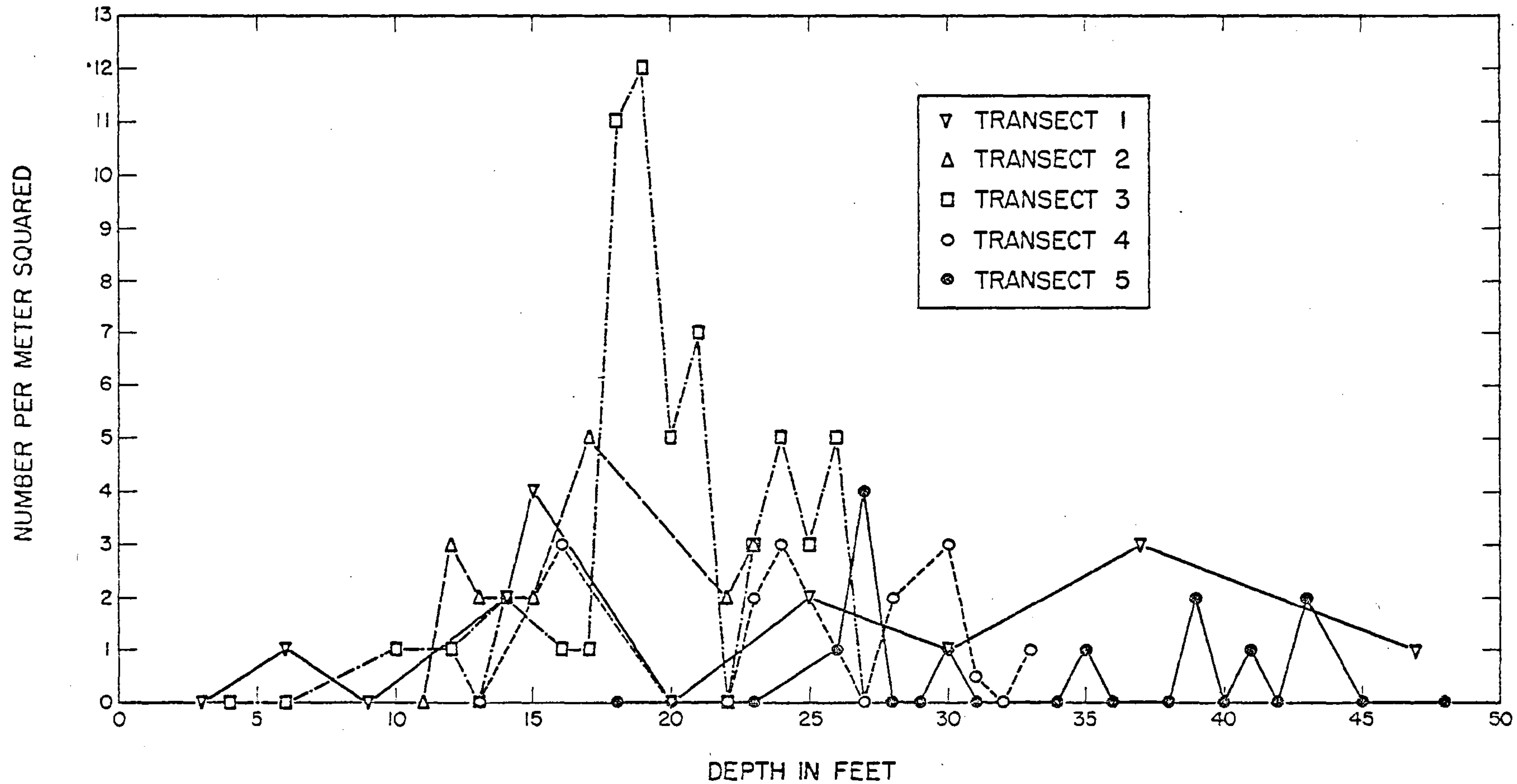

FIGURE 27. Density of the urchin, Heterocentrotus mammillatus, as a function of depth at selected regions of Honaunau Bay and Alahaka Bay. Transects 1 through 4 are in Honaunau Bay, Transect 5 in Alahaka Bay.

Ebert's study (Doty, 1968: Figs. 29-30) at Kealakekua Bay. Only mean values for Echinothrix and Tripneustes were plotted (Fig. 26) since so few specimens were counted. Work at Alahaka Bay was limited and hence was not graphed. The populations did not differ significantly from Honaunau Bay.

Heterocentrotus mammillatus, the slate pencil urchin, was fairly abundant from a depth of ten feet on down to the end of coral growth. In terms of biomass, it is the most important urchin in Honaunau Bay, but its average density was less than Ebert calculated from Kaawaloa Cove, Kealakekua Bay. The difference is particularly striking in the upper fifteen feet. Ebert found lower densities of slate pencil urchins in less protected waters, and Honaunau is less protected than Kaawaloa Cove. On the other hand, the densities counted below 17 feet on Transect 3 were as high as some of the higher densities found in Kaawaloa Cove. This is perhaps related to less water movement in this area of the bay.

As noted in Chapter 4, the distribution of Heterocentrotus could not be correlated with any factor of the coral community. It is difficult (Doty, 1968) also to relate its distribution to such ecological factors as depth, substrate, exposure, food, animal behavior and chance. It is the most abundant urchin in the exposed and sparkling clear waters from two to four fathoms depth off Hookena, south of Honaunau Bay and likewise along the sea wall but only at depths under one fathom in protected and polluted Kailua Bay, north of Honaunau. Moreover, excepting along the Kona Coast and at a few sites on Maui such as Molokini Reef, Heterocentrotus is not common in Hawaii.

Echinometra oblonga, a short-spined black urchin, was found only in the upper ten feet. It is especially abundant just below the inter-tidal zone. A set of counts using a 1/4-meter-square quadrat at the base of Transect 2 indicated densities of up to 436 per square meter, but as might be expected, the individuals were very small. Although Ebert's transects did not include E. oblonga, it is nevertheless present at Kaawaloa Cove. Its greater abundance in Honaunau Bay is undoubtedly a reflection of greater surf action, as similar densities have been measured on the more exposed south shore of Kealakekua Bay and at several similar locations around Oahu.

Echinometra mathaei, the short-spined pink or green urchin, was the most abundant urchin found in the present survey. Its average density is slightly less than 60 per square meter at a depth of five feet. It was less abundant in shallower and also in deeper water with a sharp drop in abundance below 15 feet, yet specimens were recorded down to 31 feet at Honaunau Bay and to 38 feet in Alahaka Bay. The distribution in Kaawaloa Cove, Kealakekua is similar, although there it was found to a depth of 45 feet, and at five feet an average of only ten urchins per square meter was recorded. Again this may be due to the reduced surf action at Kaawaloa Cove. Similar to *E. oblonga*, the densities also of this species measured on the exposed south shore of Kealakekua Bay and at several locations around Oahu more closely approximate those found in Honaunau.

The urchins *Echinothrix* and *Tripneustes* were not recorded frequently enough to make statistically significant about their abundance. Curiously, both are in far more frequent at Kaawaloa Cove. Also, Tripneustes is the most abundant urchin at visible depths exceeding two fathoms in Keauhou Bay and Kailua Bay, both north of Honaunau, and *Echinothrix diadema* is the most important urchin in terms of biomass at depths of less than one fathom in Keauhou Bay. Ebert suggested that for Kealakekua Bay, *Tripneustes* seems more dense below 20 feet, and *Echinothrix* more dense at fairly shallow depths.

The average density for all urchins in Honaunau Bay was 9.0 per square meter. Excluding *Echinometra* the average density was 2.3 per square meter. This latter value is comparable to Ebert's highest values for Kaawaloa Cove, and is higher than in any other area of Kealakekua Bay. This may be seen in Ebert's Table 9. His values were obtained by the point quarter method and excluded *Echinometra*.

Ebert also measured urchin density at Honaunau Bay. He used the point quarter method and again ignored *Echinometra*. Between depths of 10 and 35 feet in the area of our Transect 2 he obtained densities of one to two urchins per square meter. Our quadrat measurements in the same area indicated an average density of all urchins except *Echinometra* of 2.4 urchins per square meter.

Ebert included in his report one quadrat transect made one mile south of Honaunau Bay. In depth and topography it was comparable to our Alahaka Bay transect. He calculated an average density for all urchins of 0.93 per square meter and for all except Echinometra 0.83 per square meter. Our densities at Alahaka were 1.2 and 0.6 per square meter, respectively.

The total urchin biomass as a function of depth was plotted (Fig. 28) using Ebert's values for the average weight of an urchin of each species. As was calculated for Kaawaloa Cove, the biomass at Honaunau Bay decreases quickly with increasing depth. However, due to the lower densities of Echinothrix and Heterocentrotus, the absolute values are much lower for Honaunau Bay.

Mention should be made of a large, protected inlet immediately west of Hale-o-Keawe. It is only a foot or so deep, but contains absurdly large populations of Echinometra, Echinothrix, Tripneustes and Diadema. In one square meter 31 Tripneustes and 85 Echinometra mathaei were counted. Certainly every effort should be made to preserve this easily accessible biological laboratory and marine-life exhibit. A tidepool in front of the park headquarters also contains an abundance of Echinometra mathaei.

Few other echinoderms were observed in Honaunau Bay. About three Acanthaster crown-of-throns starfish, a number of ophiuroids and a few holothurians were seen. The greatest number of ophiuroids and holothurians were seen in the Hale-o-Keawe inlet.

In his discussion of Kealakekua Bay urchin populations, Ebert lists six factors which possibly are important in urchin distribution: depth, substrate, exposure to waves, food, animal behavior and chance. A seventh possibility is predators, whether on the larvae or on the adults. Depth is certainly the most abvious factor, but it is not a single factor. Surely its most important component is water movement, itself related also to distance from shore and exposure to waves. Possibly less important factors which vary regularly with depth are solar radiation, temperature and the abundance of other biotic forms. Whatever the component cause, the dominance of Echinometra above a depth of 10 feet and Heterocentrotus below 10 feet is easily seen.

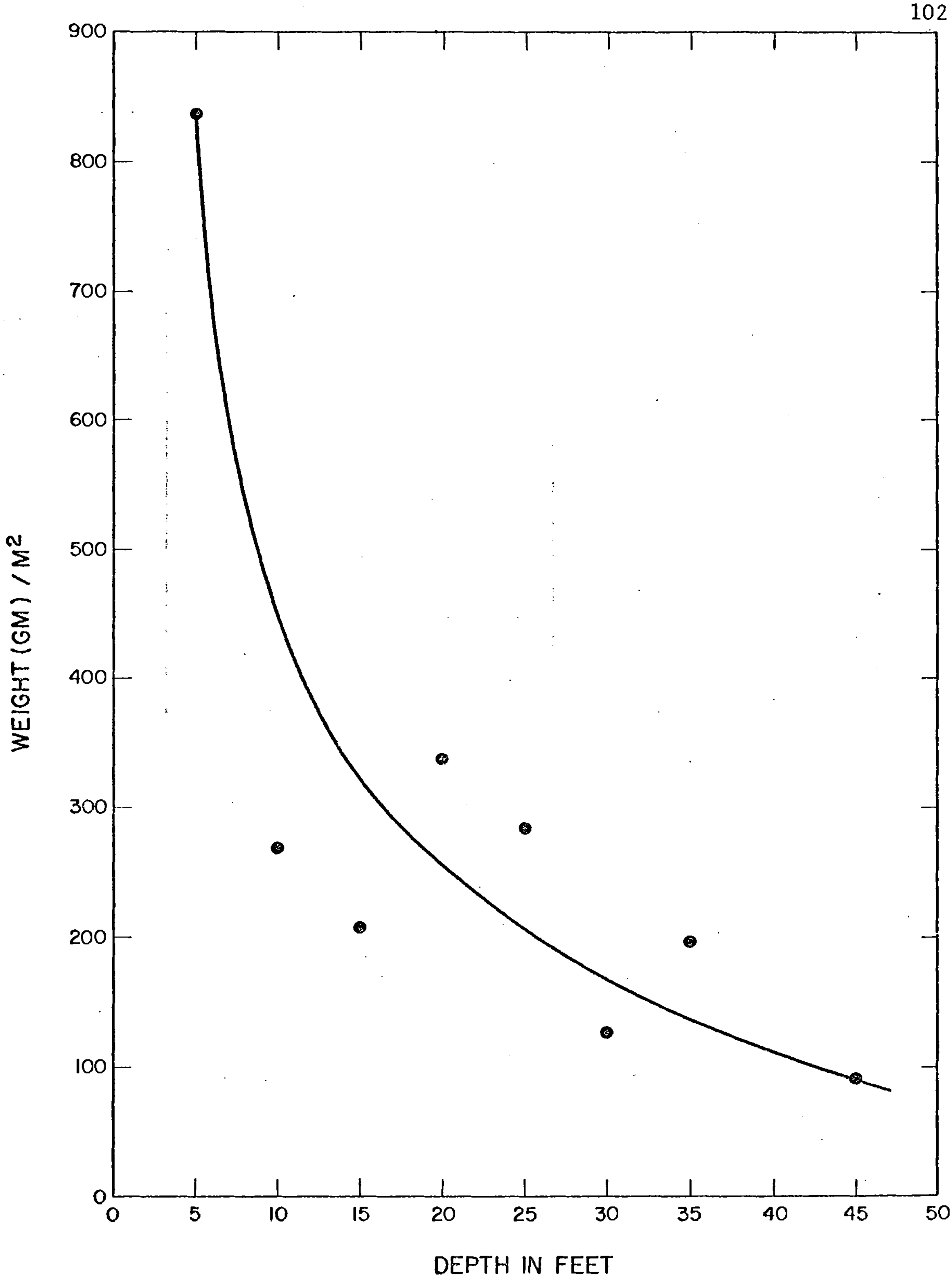

FIGURE 28. Urchin biomass at Honaunau Bay as a function of depth.

Although insufficient counts of *Echinothrix* and *Tripneustes* were recorded to outline their distribution, it does appear (Doty, 1968) that *Tripneustes* is most abundant in protected areas of low relief with little coral. The large populations of these two urchins, together with *Echinometra*, in the Hale-o-Keawe inlet lead one to suspect that reduced water movement, reduced competition, reduced predation or increased food availability may individually or collectively produce denser populations of these urchins.

In terms of overall biomass, urchins along with corals and fish comprise the top three animal groups in Honaunau Bay. Corals provide shelter for both adult and juvenile fish and urchins. The urchins and some fishes compete with each other for algae and also prevent algae from smothering the corals. Changes in any of these three groups would probably have drastic effects upon the other two.

Chapter 11

CRUSTACEA

A. Shrimp.

The only larger crustacean seen in numbers was the "cleaning shrimp", *Stenopus hispidus*. Although it seems likely that many smaller decapods live among the deep interstices of the coral, it seems equally likely that such crustaceans would occur among the coral rubble bordering the deep sand. Several coral fragments were overturned without noting such crustacea.

B. Lobsters.

The population of spiney lobsters (*Panulirus japonicus*) in the area was thought scant considering the amount of cover. A few were observed in deep crevasses along the rough shoreline north of Alahaka Bay, and in "pukas" or cracks near the bases of several exposed boulders northwest of Hale-o-Keawe.

Spiney lobsters prefer rough waters and are hence in greater abundance on the windward side of Hawaii. Also, as might be expected, there is a human foraging factor affecting the population size. The occurrence of lobsters sharply increases approaching the uninhabited regions south of Honaunau Bay beyond Hookena.

Slipper lobsters (*Paribaccus antarcticus*) were not observed. They are often gathered in shallow waters of Oahu for human consumption.

C. Crabs.

The Kona crab (Ranina serrata) is commercially the most valuable crab in Hawaii. Because of the bottom topography, however, they are not trapped in Honaunau Bay.

Kona crabs were not observed by SCUBA divers during the present study as, besides their habitat, the crabs are dawn feeders. They remain burrowed in sand during the day.

Kealakekua Bay has a flat, sandy bottom at depth 300 feet. Here

Kona crabs are trapped. A similar sandy shelf exists at depth 200 feet 500 m off Puuhonua Point and extends south 150 m off Alahaka Bay. Kona crabs are sporadically trapped at this depth off Alahaka Bay, and in times past it is reported the population has been severely decimated in this manner.

The red pebblecrab (Etisus splendidus) was infrequently observed around Honaunau. Seven-eleven crabs (Carpilius maculatus) are caught at night with lights along the rough shoreline south of Puuhonua Point and in shallow waters off Miana Point.

Ama crabs (Grapsus grapsus) are very common, small, black crabs which scramble about intertidal rocks. They are popularly gathered and eaten raw with salt as a delicacy.

Chapter 12

FISH

(Adapted from the State Division of Fish and Game's fish survey reports)

Introduction

This is a summary of the Division of Fish and Game's fish survey activities at Kealakekua Bay and Honaunau Bay, Kona, Hawaii. During the period from June through February, 1969, four fish surveys were made in the area in June, August, October and February. (For exact dates and activities during these surveys see quarterly survey reports by the Division of Fish and Game, State of Hawaii.)

In June, a preliminary surface survey was made at Kaelakekua Bay and Honaunau Bay to select sites for our permanent fish survey stations. Seven stations were selected, five (Fig. 29) in Kealakekua Bay and two (Fig. 30) in Honaunau Bay. The locations and directions of these stations are described in charts submitted with the quarterly survey report.

At each station, we laid a permanent stainless steel underwater transect line 250 yards long with title blocks spaced 25 yards apart to keep the line in place. The transect line at Station 3 (Kealakekua Bay) was not laid on the first survey (June), but established on the second survey (August). The line at Station 2 (Kealakekua Bay) was of nylon and changed to stainless steel on the second survey. The transect line at Station 5 was 200 yards long and extended to 250 yards in August. The landmarks used to locate each transect line are presented in the first quarter survey report.

To survey the fishes at each station, we used two divers swimming along each side of the transect line, identifying, counting and estimating sizes of the fish within 20 feet of the line. For a distance of 250 yards or 750 feet, the 40-foot-wide strip (20 feet on each side) equals 30,000 sq. feet or 0.7 of an acre. The fish counts are later converted (Tables 14 through 40) to total pounds of each species with length-weight constants and expressed as pounds of fish per acre.

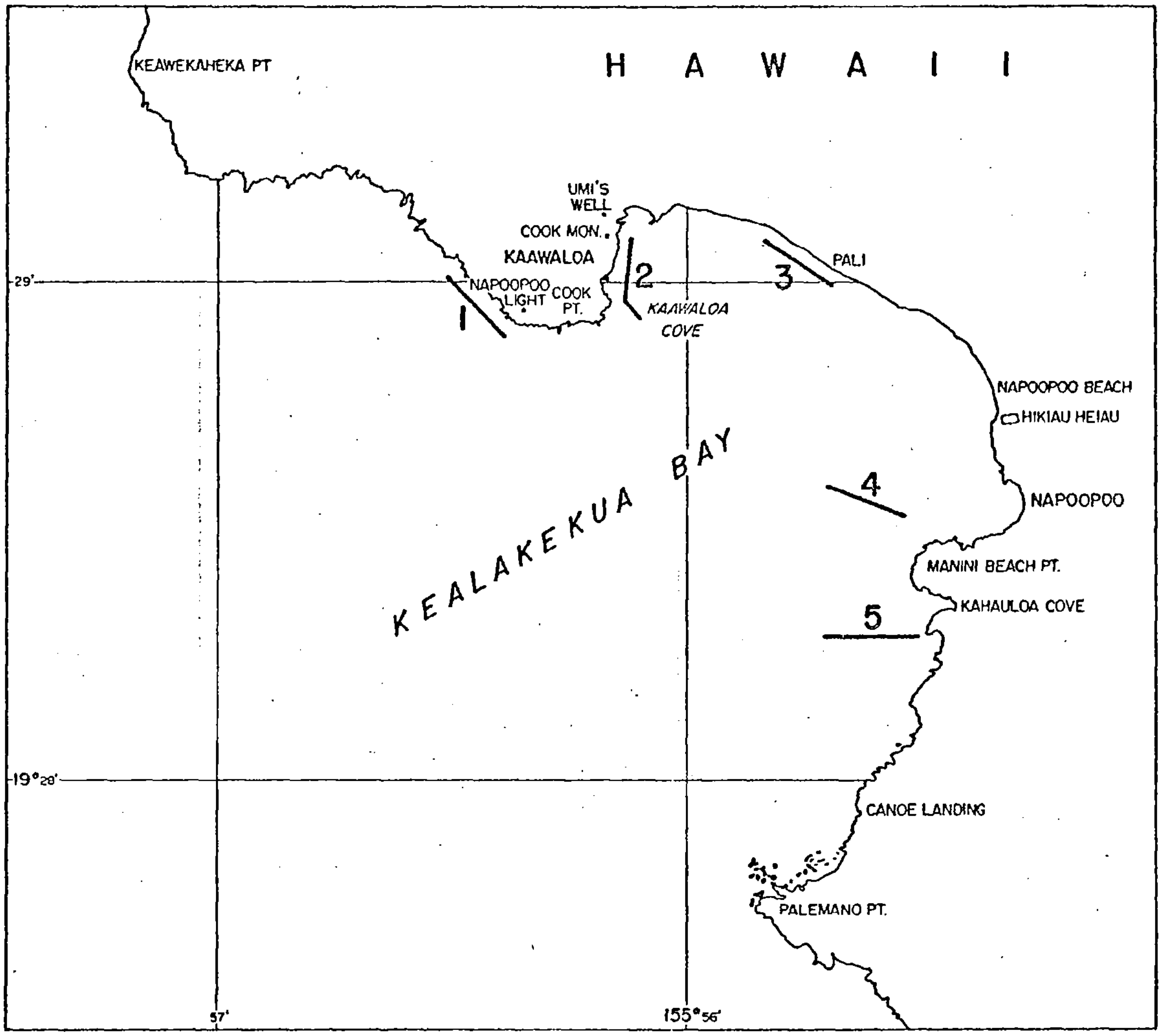

FIGURE 29. Fish transect lines, Kealakekua Bay. Lines 1 through 5 are indicated.

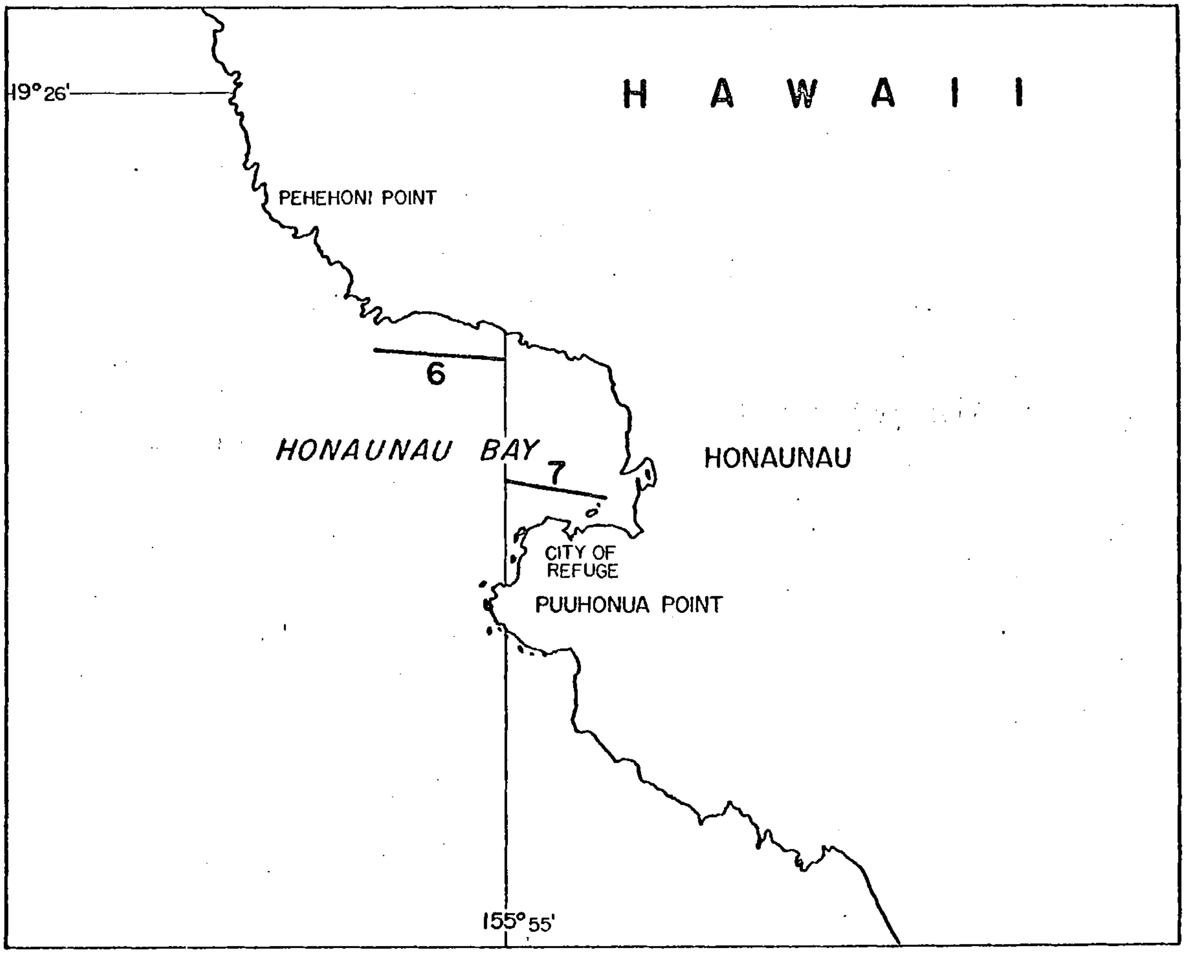

FIGURE 30. Fish transect lines, Honaunau Bay. Lines 6 and 7 are indicated.

Results

The following are summaries of numbers of fishes counted, species composition and pounds of fishes per acre.

Number of fishes counted

The number of fish counted at each station (Table 8) ranged fron 520 to 2,827 with an over-all average of 1,179 fish counted per station. The largest average number of fishes (1,833 was counted on Station 7 in Honaunau Bay and the lowest average counts occurred on Stations 4 and 5 in Kealakekua Bay.

TABLE 8. Number of fish counted at each station on each survey.

	Kealakekua Bay					Honaunau Bay		
Survey	Station 1	2	3*	4	5	6	7	
June	1,073	1,133	-	561	616	925	2,366	
Aug.	918	1,064	583	716	533	1,623	975	
Oct.	912	1,937	1,356	673	792	2,106	2,170	
Feb.	520	2,827	803	745	580	1,761	1,820	
MEAN	856	1,740	914	674	630	1,604	1,833	1,179

*Station 3 established in August.

Species composition

One hundred and twenty-one different species of fishes were observed in Kealakekua Bay and Honaunau Bay (Table 13) on the initial three surveys. Of this, 110 species were found in Kealakekua Bay and 98 species were found in Honaunau Bay.

Of the fishes in Kealakekua Bay, 32 species were found at all five stations. In Honaunau Bay, 59 of the species were found at both of the two stations. Among the different species in Kealakekua and Honaunau Bays, there were 87 species that occurred on the surveys at all stations and there were 13 species (Table 9) that were present at all stations during every survey.

TABLE 9. Fish species observed at all stations on every survey in Kealakekua Bay and Honaunau Bay.

	Scientific Name	Common Name
1.	Centropyge potteri	Potter's angel
2.	Chaetodon ornatissimus	Orange stripe butterfly
3.	C. multicinctus	
4.	Chromis leucurus	White-tail damsel
5.	Ctenochaetus strigosus	Kole
6.	Forcipiger longirostris	Long-nose butterfly
7.	Naso lituratus	Kala
8.	Parupeneus multifasciatus	Moano
9.	Pomocentrus jenkinsi	Yellow eye damsel
10.	Scarus dubius	Uhu
11.	Zanclus canescens	Kihikihi
12.	Zebrasoma flavescens	Yellow tang
13.	Thalassoma duperreyi	Hinalea

The number of species observed at each station (Fig. 31, Table 10) ranged from 34 to 65 with an average of 48 species per station. There is a descrepancy in the fourth survey on Station 1 between a relatively low number of species observed and a relatively high weight of fish per acre calculated. During this survey the seas were quite rough and only half the line was surveyed. The constant for determining pounds per acre was therefore accordingly increased.

Pounds per acre

The standing crop of fishes (Fig. 32, Table 11) ranged from 58 to 603 pounds per acre with an average of 270 pounds per acre per station. The stations in Kealakekua Bay had an average of 233 pounds of fish per acre and in Honaunau Bay there was an average of 364 pounds of fish per acre. The reason Kealakekua Bay has fewer pounds per acre

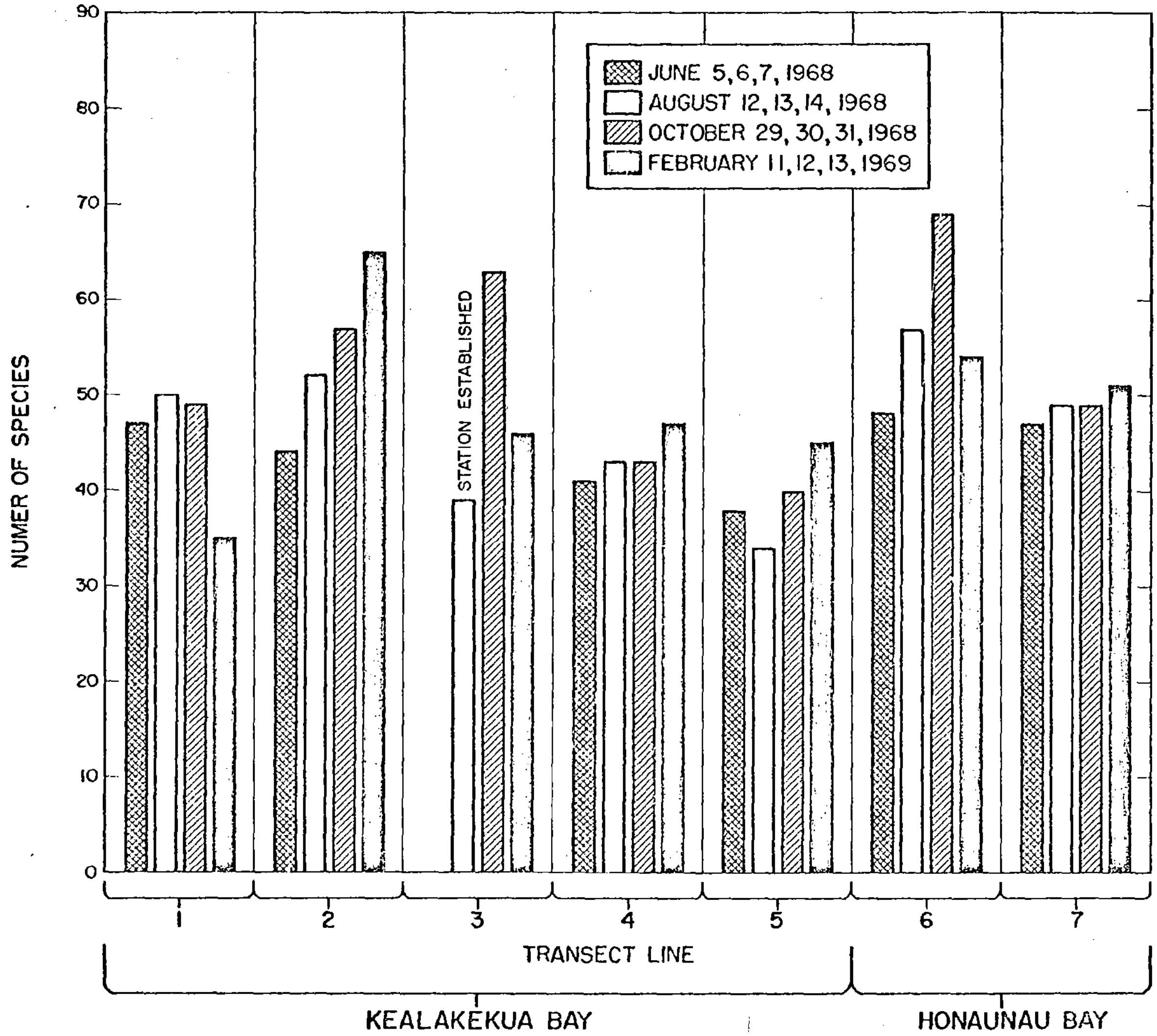

FIGURE 31. Comparison of number of species of fishes observed during three surveys at the seven permanent transect stations in Kealakekua Bay and Honaunau Bay.

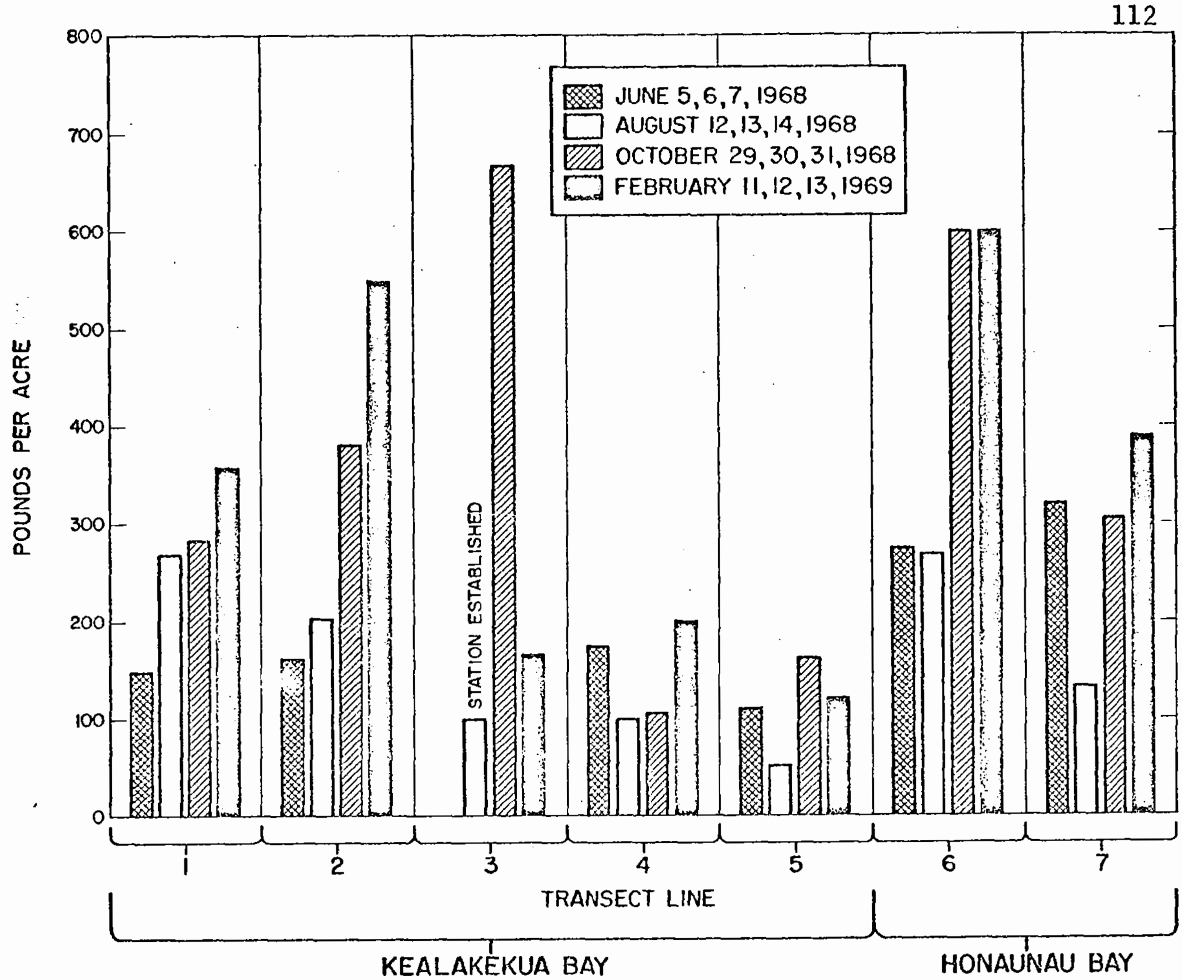

FIGURE 32. Comparison of pounds per acre of fishes observed during three surveys at the seven permanent transect stations in Kealakekua Bay and Honaunau Bay.

than Honaunau Bay is because the substratum is largely sandy with very few fish. This is exemplified in Stations 4 and 5.

TABLE 10. Number of fish species observed at the stations during surveys.

	Kealakekua Bay					Honaunau Bay		
Survey	Station 1	2	3*	4	5	6	7	
June	47	44	-	41	38	48	47	
Aug.	50	52	39	43	34	57	49	
Oct.	49	57	63	43	40	69	49	
Feb.	35	65	46	47	45	54	51	
MEAN	45	54	49	44	39	57	49	48

*Station 3 established in August.

TABLE 11. Pounds per acre of fishes in Kealakekua Bay and Honaunau Bay, Hawaii.

	Kealakekua Bay					Honaunau Bay		
Survey	Station 1	2	3*	4	5	6	7	
June	151	163	-	175	111	276	324	
Aug.	267	204	102	102	58	274	138	
Oct.	283	385	669	107	163	603	306	
Feb.	358	548	167	201	122	599	388	
MEAN	265	325	313	146	114	438	289	270

* Station 3 established in August.

The more common fishes in Kealakekua Bay and Honaunau Bay are arranged (Table 12) serially. Of the 34 species involved in this comparison, the yellow tang (Zebrasoma flavescens) and kole (Ctenochaetus strigosus) occurred at all seven stations and are the commonest and most numerous species in both bays. It was previously mentioned that these two species were present at every station and on every survey.

As noted in Table 12, numerous species are commonly recorded in Honaunau Bay but not in Kealakekua Bay, and vice versa. This reflects ecological niches to which certain species are adapted. For example, Station 6 is situated on a steep shoulder or drop-off blanketed by finger coral (*Porites compressa*) with a red alga, *Tolypiocladia* sp., growing in the interstices. No other station has quite this exposure and topography, and two species in great abundance here but uncommon elsewhere are *Acanthurus guttatus* and *Naso unicornis*. Similarly such species adapted to special conditions are associated with each of the seven stations.

Kole (*Ctenochaetus strigosus*) is a common species of fish throughout the islands, whereas Hawaiian kole (*C. hawaiiensis*) is common in Kealakekua Bay and Honaunau Bay, but uncommon in most areas of the Hawaiian Islands. These species live between boulders and coral mounds and feed on microorganisms. Just why the latter is common here is not known.

Finally, it should be noted that in Kealakekua and Honaunau Bays, there are "spots" away from the permanent stations that contain species not seen along the transect lines. For example, it was reported that Kona crabs (*Ranina serrata*) are present in the sandy bottom at Stations 4 and 5. There is also reported to be a "moi hole" along the surf zone near Palemano Point in Kealakekua Bay. During the process of locating the transect lines on Station 4, we have also seen large rays (both *Aetobatus narinari* and *Manta birostris*).

TABLE 12. The frequency of occurrence as expressed in pounds per acre of the more common fish species in Kealakekua Bay and Honaunau Bay, June through October, 1968.

Species	Average Lbs./Acre on Stations 1	Kealakekua Bay 2	3	4	5	Honaunau Bay 6	7
Zebrasoma flavescens	15	22	13	13	9	35	22
Ctenochaetus strigosus	15	18	19	9	14	30	14
Scarus perspicillatus	51	18	14	9	11	12	
Naso lituratus	23	15	10	5	13	36	
Scarops jordani	30	30		23	24		
Acanthurus leucopareius	9	25	17			13	
Scarus dubius	15			13	8		
Acanthurus olivaceus	25	11		8			
A. achilles		22	10				
A. dussumieri					4		14
Dascyllus albisella				38			19
Melichthys buniva		15					15
Scarus sordidus	25						
Acanthurus xanthopterus			13				
A. guttatus						28	
A. nigrosis		16					
Naso brevirostris	18						
N. unicornis						86	
N. hexacanthus							11
Iso hawaiiensis						29	
Thalassoma duperreyi			12				
Chromis verater					10		
C. leucurus					4		
Chanos chanos						41	
Zanclus canescens						11	
Chaetodon ornatissimus							18
Mulloidichthys samoensis							25
M. auriflamma							9
Myripristis berndti							14
Carangoides ajax			385				
Polydactylus sexfilis			36				
Aprion virescens				23			
Gymnothorax flavimarginatus				6			
Cheilinus rhodochrons					4		

TABLE 13. Fishes observed in Kealakekua Bay and Honaunau Bay, June through October, 1968.

COMMON NAME	SCIENTIFIC NAME	Average Pounds/Acre Kealakekua					Honaunau	
	Line No:	1	2	3	4	5	6	7
Lizard fish	Synodous variegatus				.71		.06	.80
Eel - Puhi paka	Gymnothorax flavimarginatus				6.10			1.81
	G. steindachneri		.76					
Cornet fish	Fistularia petimba	.98	.40	.17				.05
Trumpet fish	Aulotsomus chinensis	.46	1.19	.53	.29	.04	.50	3.88
Squirrel fish	Holocentrus ensifer				.45	.24		
Alaihi	H. xantherythrus			.03	.11		.25	.06
	H. diadema	.05						
	H. sammara		.37		.73			
	Holotrachys lima							3.57
U'u	Myripristis berndti	.84	1.40	.99	3.33	2.89	4.44	14.28
	M. multiradiatus						.16	
Introduced Grouper-Roi	Cephalopholis argus	.48					.73	
Aweoweo	Priacanthus cruentatus							.84
Upapalu	Apogon snyderi			.18	.40		.06	.35

TABLE 13. (continued)

COMMON NAME	SCIENTIFIC NAME	Average Pounds/Acre Kealakekua						Honaunau
	Line No.	1	2	3	4	5	6	7
Kahala	Seriola dumerilii		2.94				1.51	
White ulua	Carangoides ajax			385.39				
Omilu	Caranx melampygus		5.42				4.65	
Lae	Scomberoides sancti-petri		4.83					
Uku	Aprion virescens				22.50		.87	
Gurutsu	Aphareus furcatus	.98	1.51			.30	.87	
Spot weke	Mulloidichthys samoensis		.36	7.39	2.38	.71	.24	25.38
Red weke	M. auriflamma		.07	.57	.08		.86	8.87
Malu	Parupeneus pleurostigma	.26	3.13	.20	.67		.08	.14
Kumu	P. porphyreus			.72				1.93
Manu	P. bifasciatus	4.23	4.07		.34	.16	2.31	.71
Moano	P. multifasciatus	1.61	2.29	2.30	1.33	1.49	5.25	2.34
Moana kea	P. chryserydros	.97	3.10	1.25	.38		.37	
Mu	Monotaxis grandoculis	3.33	.28		1.18	1.41	3.52	.56
Black-white angel	Holacanthus arcuatus	.10			.10			.41
Potter's angel	Centropyge potteri	.78	.70	.88	.69	1.81	1.56	3.25
Longnose butterfly	Forcipiger longirostris	1.44	1.74	1.12	.55	.72	3.73	2.60

TABLE 13. (continued)

COMMON NAME	SCIENTIFIC NAME	Average Pounds/Acre Kealakekua					Honaunau	
	Line No.	1	2	3	4	5	6	7
Blue stripe	Chaetodon fremblii	.26	.66	1.64	.30	.11	1.23	.62
Corallicola	C. corallicola				.31			
Cross striped	C. auriga		2.30		.27			
Orange striped	C. ornatissimus	3.55	4.96	4.65	2.13	2.12	6.01	18.10
Puka	Chaetodon miliaris			.09				.29
	C. trifasciatus	.38	.19	.64				.09
	C. multicinctus	2.00	5.10	3.53	2.27	1.69	4.02	4.45
	C. unimaculatus	.08	.55	.15	.09	1.21		
	C. lunula	1.15	2.33	3.54	.20	.42	1.04	.74
	C. quadrimaculatus	.78	.87	.62		.18	1.40	
	Hemitaurichthys zoster		.18	.18			.09	
Pilikoa	Paracirrhites cinctus	.60	.17	.31		.23	.58	
	P. forsteri	1.56	2.47	1.63	1.02	.30	.35	.36
	P. arcatus	.51	.14	.20			.55	.07
Poo-paa	Cirrhitus alternatus	.60	1.19	.50			.25	

TABLE 13. (continued)

COMMON NAME	SCIENTIFIC NAME	Average Pounds/Acre Kealakekua 1	2	3	4	5	Honaunau 6	7
	Line No.	1	2	3	4	5	6	7
Maomao	Abudefduf abdominalis		5.12	.74	2.28	2.03	3.25	
Kupipi	A. sordidus			.79			.12	
	A. imparipennis	.14						
	Pomacentrus jenkinsi	1.79	5.79	3.75	.31	.68	4.91	2.12
Aloiloi	Dascyllus albisella		.11		7.97		6.56	18.92
	Chromis dimidiatus		.09	.05			.01	
White tail	C. leucurus	.46	2.42	.60	1.80	4.36	5.69	2.50
Black damsel	Chromis verater	2.72	1.44		3.29	9.70	6.94	6.69
Blue damsel	C. ovalis	3.16	.70		.20	.19	3.06	2.79
	C. vanderbilti		.06					
A'awa	Bodianus bilunulatus				.85			
Hinalea lauwili	Thalassoma duperreyi	4.69	8.74	12.21	2.77	2.28	6.94	6.69
Hinalea luahine	T. ballieui	.19	.47		.40	.28	1.67	1.34
	T. lutecens					.06		
	T. fuscum	.96						
	T. umbrostigma			.28				

TABLE 13. (continued)

COMMON NAME	SCIENTIFIC NAME	Average Pounds/Acre Kealakekua 1	2	3	4	5	Honaunau 6	7
	Line No.	1	2	3	4	5	6	7
Birdfish (hinalea i'iwi)	Gomphosus varius	.89	1.81	.64	.24	.18	.57	.20
Hinalea lolo	Coris gaimardi	.67	.80	.31	1.59	1.16	.88	2.42
Hilu	C. flavovittata					.01		.27
Opule	Anampses cuvieri	.12	.92		.22		.30	.36
	A. rubrocaudatus						.02	.11
Labroides	Labroides phthirophagus	.04	.07	.12	.05	.04	.07	.08
	Novaculichthys taeniourus	.24	.71	.24	.32	.24	.14	.14
	Pseudocheilinus octotaenia					.06	.05	.05
Ohua	Stethojulis albovittata	.05				.10	.59	.10
Omaka	S. axillaris	.17	.19	1.11	.19	.52	.04	.10
Poou	Cheilinus rhodochorous	2.51	.10		.23	3.67	.30	1.55
	C. bimaculatus							1.05
Uhu	Scarus dubius	14.92	9.15	9.66	12.98	7.69	4.77	6.80
Band snout	S. perspicillatus	50.89	17.59	13.74	8.71	11.16	11.97	8.10
	S. sordidus	25.40			1.88	2.43	3.90	2.79

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TABLE 13. (continued)

COMMON NAME	SCIENTIFIC NAME	Average Pounds/Acre						
		Kealakekua					Honaunau	
	Line No.	1	2	3	4	5	6	7
	Scarops jordani	30.11	30.11		23.13	23.52	1.88	
Sleeping uhu	Calotomus sandvicensis	8.13	1.32		.60		.25	1.20
Kihikihi	Zanclus canescens	3.77	4.33	3.33	1.09	2.80	10.79	3.37
Surf maiko	Acanthurus guttatus		.23				28.41	
Pakuikui	A. achilles	4.28	22.05	9.84	.16	.68	1.17	.44
White-banded maiko	A. leucopareius	9.33	24.63	17.23	.49		12.53	.61
Maiko	A. nigrofuscus	2.61	2.11	4.71	1.00	1.15	1.98	1.13
	A. nigroris	2.23	15.64	2.40	.27	1.27	2.48	2.62
Naenae	A. olivaceus	24.85	11.44	2.26	8.04	2.45	1.20	4.23
Manini	A. sandvicensis	.12	5.27	1.52			1.96	2.44
Palani	Acanthurus dussumieri	4.44	4.55	5.64	1.09	3.81	5.16	13.82
Pualu	A. xanthopterus		.30	13.05	.37	.19	2.93	.22
	A. mata	1.40		4.22			3.05	3.00
	A. thompsonii	1.61	.82		.36			.02
Kole	Ctenochaetus strigosus	14.89	17.73	19.48	8.62	13.93	30.08	14.44

TABLE 13. (continued)

COMMON NAME	SCIENTIFIC NAME	Average Pounds/Acre — Kealakekua 1	2	3	4	5	Honaunau 6	7
	Line No.	1	2	3	4	5	6	7
Hawaiian kole	C. hawaiiensis		.30	.09	.17	.10	.23	.26
Yellow manini	Zebrasoma flavescens	15.18	21.97	13.11	13.02	8.86	35.36	22.88
Sailfin tang	Z. veliferum		8.83		.48	.16	1.24	.48
Kala	Naso hexacanthus						8.62	11.38
Horned kala	N. brevirostris	17.78		1.46				
Kala	N. unicornis	5.84	6.33				86.35	
	N. lituratus	22.98	15.02	10.30	4.71	12.62	35.89	5.44
Humuhumu	Balistes bursa	3.52	.53	1.12	1.10	2.27	1.67	3.97
Humuhumi-mimi	B. capistratus					.74	.31	
Humuhumu-uli	Melichthys vidua	.10		1.04	1.04	.40	2.76	1.71
Humuhumu-ele'ele	M. buniva	4.46	15.29	.81		.51	1.91	14.90
	Xanthichthys ringens	1.63		.16				2.60
Humuhumunukunukuapuaa	Rhinecanthus aculeatus		.31					
Humuhumunukunukuapuaa	R. rectangulus		1.58	1.11				
Ohua	Amanses sandwichiensis		1.38					

TABLE 13. (continued)

COMMON NAME	SCIENTIFIC NAME	Average Pounds/Acre Kealakekua 1	2	3	4	5	Honaunau 6	7
	Line No.	1	2	3	4	5	6	7
Oili uwiwi	Pervagor spilosoma	.41	.16	.50	.27	.09	.43	.12
Moa	Ostracion lentiginosus	X	X	X			X	X
Smooth puffer	Arothron hispidus		2.33				2.30	
Banded puffer	Canthigaster cinctus				.19			
Spotted puffer	C. jactator	.11	.18	.09				.07
Sharp nose puffer	C. rivulatus							.33
Blenny	Blennidae (unidentified)		X					X
	Cirripectus obscurus			X			X	
	Iso hawaiiensis						29.04	
Aawa	Chanos chanos						40.65	
Moi	Polydactylus sexfilis			36.30				
Lion fish	Pterois sphex			.07				
Lobster	Panulirus penicillatus		7.26					
Fairy shrimp	Stenopus hispidus							X

X = observed but weight not determined

TABLE 14. Fish species, number, length and weight observed on transect 1, 6-VI-68, 1030 to 1107 hours. The transect begins at depth 27 feet and ends at depth 20 feet. Accounted for are 47 species and 150.79 pounds of fish per acre.

COMMON NAME	SCIENTIFIC NAME	No. fish $\bar{x}$ l. in inches	Weight in Pounds Σ for fish	Per acre
Cornet fish	Fistularia petimba 2 - 12	1 - 24	.345	.50
U'u	Myripristis berndti	1 - 6	.164	.24
Gurutsu	Aphareus furcatus	1 - 12	1.037	1.51
Malu	Parupeneus pleurostigma	1 - 6	.097	.14
Moano	P. multifasciatus 3 - 8"	16 - 4	1.357	2.00
Moana kea	P. chryserydros	1 - 12	.916	1.33
Potter's angel	Centropyge potteri	16 - 3	.480	.70
Longnose butterfly	Forcipiger longirostris	21 - 5	1.2345	1.79
Orange striped	Chaetodon ornatissimus	18 - 5	2.610	3.79
	C. lunula	4 - 6	.942	1.37
	C. multicinctus	25 - 4	1.664	2.42
	C. quadrimaculatus	3 - 4	.182	.26
Pilikoa	Paracirrhites forsteri	3 - 8	1.075	1.56
Yellow eye damsel	Pomacentrus jenkinsi	18 - 4	1.083	1.57
White tail	Chromis leucurus	15 - 3	.478	.69
Black damsel	C. verater	35 - 5	4.244	6.16
Blue damsel	Chromis ovalis	110 - 2	.739	1.07
Hinalea lauwili	Thalassoma duperreyi	77 - 4	2.365	3.43
Birdfish (hinalea i'iwi)	Gomphosus varius	22 - 4	.451	.65
Hinalea lolo	Coris gaimardi	5 - 6	.475	.69
Opule	Anampses cuvieri	1 - 6	.130	.19

TABLE 14.(continued)

COMMON NAME	SCIENTIFIC NAME	No. fish x̄ l. in inches	Weight in Pounds for fish	Per acre
Labroides	Labroides phthirophagus	1 - 4	.029	.04
	Novaculichthys taeniourus	1 - 6	.162	.24
Omaka	Stethojulis axillaris	1 - 4	.033	.05
Poou	Cheilinus rhodochrous	9 - 7	1.729	2.51
Green & red	Thalassoma fuscum	11 - 5	.66	.96
Uhu	Scarus dubius 16 - 6"	1 - 18	6.966	10.11
Kihikihi	Zanclus canescens	30 - 4	2.342	3.40
Pakuikui	Acanthurus achilles 24 - 4"	2 - 6	1.693	2.46
White-banded maiko	A. leucopareius	27 - 8	10.783	15.66
Maiko	A. nigrofuscus	74 - 4	3.078	4.47
Maiko	A. nigroris	25 - 4	1.088	1.58
Naenae	A. olivaceus	34 - 8	11.837	17.19
Manini	A. sandvicensis	1 - 4	.054	.08
Palani	A. dussumieri	5 - 8	1.869	2.71
Pualu	A. mata	13 - 5	1.219	1.77
Kole	Ctenochaetus strigosus	141 - 4	8.483	12.32
Yellow manini	Zebrasoma flavescens	170 - 4	9.574	13.90
Kala	Naso unicornis	5 - 10	3.200	4.65
Kala	N. lituratus	16 - 8	8.274	12.01
Black	Acanthurus thompsonii	9 - 6	1.108	1.61
Humuhumu	Balistes bursa	29 - 5	3.226	4.68
Humuhumu-ele'ele	Melichthys buniva 7 - 6"	2 - 8	2.789	4.05
	Xanthichthys ringens	1 - 6	.864	1.25
Oili uwiwi	Pervagor spilosoma	13 - 4	.632	.92

TABLE 14. (continued)

COMMON NAME	SCIENTIFIC NAME	No. fish $\bar{x}$ l. in inches	Weight in Pounds $\bar{x}$ for fish	Per acre
Spotted puffer	Canthigaster jactator	3 - 3	.076	.11
Red & White anamone fish (?)		3 - 2	--	--

TABLE 15. Fish species, number, length and weight observed on Transect 1, 13-VIII-68, 1047 to 1121 hours. The transect begins at depth 25 feet and ends at dept 25 feet. Accounted for are 50 species and 266.54 pounds of fish per acre.

COMMON NAME	SCIENTIFIC NAME	No. fish $\bar{x}$ l. in inches	Weight in Pounds $\bar{x}$ for fish	Per acre
Trumpet fish	Aulostomus chinensis	1 - 16 1 - 12	.117	.17
Introduced Roi	Cephalopholis argus	1 - 8	.333	.48
Gurutsu	Aphareus furcatus	1 - 8	.307	.45
Malu	Parupeneus pleurostigma	1 - 6	.097	.14
Manu	P. bifasciatus	3 - 6	.324	.47
Moano	P. multifasciatus	9 - 6	1.030	1.50
Moana kea	P. chryserydros	1 - 8	.271	.39
Black-white angel	Holacanthus arcuatus	1 - 4	.071	.10
Potter's angel	Centropyge potteri	14 - 3	.420	.61
Longnose butterfly	Forcipiger longirostris	19 - 4	.572	.83
Blue stripe	Chaetodon fremblii	3 - 4	.182	.26
Orange striped	C. ornatissimus 4 - 6"	18 - 4	2.338	3.40
	C. trifasciatus	4 - 4	.261	.38
	C. lunula	5 - 5	.681	.99
	C. unimaculatus	2 - 3	.051	.07
	Chaetodon quadrimaculatus	4 - 4	.243	.35
	C. multicinctus	13 - 4	.865	1.26

TABLE 15. (continued)

COMMON NAME	SCIENTIFIC NAME	No. fish $\bar{x}$ l. in inches	Weight in Pounds ∠ for fish	Per acre
Pilikoa	Paracirrhites cinctus	2 - 8	.758	1.10
Pilikoa	P. arcatus	12 - 4	.561	.82
	Pomacentrus jenkinsi	20 - 3	.508	.74
White tail	Chromis leucurus	7 - 3	.223	.32
Black damsel	C. verater	12 - 4	.745	1.08
Blue damsel	C. ovalis	55 - 3	1.247	1.81
Hinalea lauwili	Thalassoma duperreyi	79 - 5	4.740	6.88
Hinalea luahine	T. ballieui	3 - 6	.130	.19
Birdfish (hinalea i'iwi)	Gomphosus varius	21 - 5	.840	1.22
Hinalea lolo	Coris gaimardi 2 - 4"	2 - 6	.246	.36
Ohua	Stethojulis albovittata	1 - 4	.035	.05
Omaka	S. axillaris	6 - 4	.200	.29
Uhu	Scarus dubius	11 - 12	14.256	20.70
Band snout	S. perspicillatus 2 - 24"	4 - 18	40.271	58.47
Limu teeth	Scarops jordani	2 - 24	20.736	30.11
	Scarus sordidus	4 - 18	17.496	25.40
Kihikihi	Zanclus canescens	23 - 4	1.796	2.61
White-banded maiko	Acanthurus leucopareius	18 - 5	1.755	2.55
Maiko	A. nigrofuscus	8 - 5	.650	.94
Maiko	A. nigroris	77 - 4	3.351	4.87
Naenae	A. olivaceus 10 - 4"	13 - 12	15.711	22.81
Manini	A. sandvicensis	1 - 5	.105	.15
Palani	Acanthurus dussumieri	11 - 4	.514	.75
Pualu	A. mata	5 - 6	.810	1.18

TABLE 15. (continued)

COMMON NAME	SCIENTIFIC NAME	No. fish $\bar{x}$ l. in inches	Weight in Pounds ∑ for fish	Per acre
Kole	Ctenochaetus strigosus	175 - 4	10.528	15.29
Yellow manini	Zebrasoma flavescens	182 - 4	10.250	14.88
Kala	Naso unicornis 1 - 12"	1 - 18	4.839	7.03
Kala	N. lituratus	8 - 12	13.962	20.27
Humuhumu	Balistes bursa 13 - 4"	9 - 6	2.471	3.59
Humuhumu-uli	Melichthys vidua	1 - 4	.070	.10
Humuhumu-ele'ele	M. buniva	8 - 8	4.506	6.54
	Xanthichthys ringens	2 - 5	1.000	1.45
Oili uwiwi	Pervagor spilosoma	2 - 4	.07	.14

TABLE 16. Fish species, number, length and weight observed on transect 1, 30-X-68, 1213 to 1246 hours. The transect begins at depth 25 feet and ends at depth 25 feet. Accounted for are 49 species and 283.05 pounds of fish per acre.

COMMON NAME	SCIENTIFIC NAME	No. fish $\bar{x}$ l. in inches	Weight in Pounds ∑ for fish	Per acre
Cornet fish	Fistularia petimba	3 - 42	4.445	6.45
Trumpet fish	Aulostomus chinensis	5 - 12	.518	.75
	Holocentrus diadema	2 - 3	.033	.05
U'u	Myripristis berndti	6 - 6	.985	1.43
Malu	Parupeneus pleurostigma	6 - 5	.338	.49
Manu	P. bifasciatus	1 - 14 8 - 10 1 - 6	5.480	7.96
Moano	P. multifasciatus	5 - 7	.909	1.32
Moana kea	P. chryserydros	2 - 10	1.060	1.54

TABLE 16. (continued)

COMMON NAME	SCIENTIFIC NAME	No. fish x̄ l. in inches	Weight in Pounds ∠ for fish	Per acre
Mu	Monotaxis grandoculis	1 - 16	2.294	3.33
Potter's angel	Centropyge potteri	10 - 4	.710	1.03
Longnose butterfly	Forcipiger longirostris	20 - 5	1.175	1.71
Orange striped	Chaetodon ornatissimus	6 - 7	2.387	3.47
	C. lunula	2 - 7	.748	1.09
	C. multicinctus	24 - 4	1.597	2.32
	Chaetodon quadrimaculatus	10 - 5	1.188	1.73
	C. unimaculatus	1 - 4	.061	.09
Pilikoa	Paracirrhites cinctus	3 - 3	.060	.09
Pilikoa	P. arcatus	7 - 3	.138	.20
Poo-paa	Cirrhitus alternatus	1 - 8	.410	.60
	Pomacentrus jenkinsi	18 - 5	2.115	3.07
White tail	Chromis leucurus	8 - 3	.255	.37
Black damsel	C. verater	3 - 6	.629	.91
Blue damsel	C. ovalis	200 - 3	4.536	6.59
	C. imparepenus	3 - 3	.096	.14
Hinalea lauwili	Thalassoma duperreyi	43 - 5	2.580	3.75
Birdfish (hinalea i'iwi)	Gomphosus varius	14 - 5	.560	.81
Hinalea lolo	Coris gaimardi	7 - 6	.665	.97
Labroides	Labroides phthirophagus	2 - 3	.024	.04
Uhu	Scarus dubius	25 - 8	9.600	13.94
Band snout	S. perspicillatus	6 - 15 3 - 18	29.820	43.30
Sleeping uhu	Calotomus sandvicensis	1 - 18 4 - 12	5.599	8.13

TABLE 16. (continued)

COMMON NAME	SCIENTIFIC NAME	No. fish $\bar{x}$ l. in inches	Weight in Pounds ¼ for fish	Weight in Pounds Per acre
Kihikihi	Zanclus canescens	24 - 5	3.660	5.31
Pakuikui	Acanthurus achilles	39 - 5	4.193	6.09
White-banded maiko	A. leucopareius	40 - 6	6.739	9.79
Maiko	A. nigrofuscus	40 - 4	1.664	2.42
Maiko	A. nigroris	2 - 5	.170	.25
Naenae	A. olivaceus	35 - 10	23.800	34.56
Palani	Acanthurus dussumieri	2 - 15 5 - 8	6.797	9.87
Pualu	A. xanthopterus	5 - 6	..864	1.26
Kole	Ctenochaetus strigosus	100 - 5	11.750	17.06
Yellow manini	Zebrasoma flavescens	105 - 5	11.550	16.77
Horned kala	Naso brevirostris	3 - 18	12.247	17.78
Kala	N. lituratus	25 - 10	25.250	36.66
Humuhumu	Balistes bursa	3 - 7 6 - 5	1.584	2.30
Humuhumu-uli	Melichthys vidua	1 - 4	.070	.10
Humuhumu-ele'ele	M. buniva	6 - 5 1 - 10	1.925	2.80
	Xanthichthys ringens	3 - 5	1.500	2.18
Oili uwiwi	Pervagor spilosoma	6 - 3	.123	.18
Moa	Ostracion lentiginosus	1 - 2	--	--

TABLE 17. Fish species, number, length and weight observed on transect 1, 12-II-69, 1140 to 1156 hours. The transect begins at depth 20 feet and ends at depth 28 feet. Accounted for are 35 species and 358.42 pounds of fish per acre.

COMMON NAME	SCIENTIFIC NAME	No. fish $\bar{x}$ l. in inches	Weight in Pounds Σ for fish	Weight in Pounds Per acre
Trumpet Fish	Aulostomus chinensis	1 - 12	.104	.30
Moano	Parupeneus multifasciatus	17 - 7	3.090	8.97
Potter's angel	Centropyge potteri	8 - 4	.568	1.65
Longnose butterfly	Forcipiger longirostris	10 - 5	.588	1.71
Blue stripe	Chaetodon fremblii	2 - 4	.122	.35
Orange striped	C. ornatissimus	8 - 7	3.183	9.24
	C. multicinctus	20 - 4	1.331	3.87
	C. unimaculatus	2 - 4	.122	.35
	C. quadrimaculatus	10 - 5	1.188	3.45
Pilikoa	Paracirrhites arcatus	5 - 4	.234	.68
White tail	Chromis leucurus	20 - 3	.637	1.85
Blue damsel	C. ovalis	33 - 3	.748	2.17
	C. vanderbilti	1 - 7	.223	.65
	Abudefduf imparipennis	5 - 2	.025	.07
Hinalea lauwili	Thalassoma duperreyi	38 - 5	2.280	6.62
Birdfish(hinalea i'iwi)	Gomphosus varius	5 - 4	.102	.30
Hinalea lolo	Coris gaimardi	8 - 5	.440	1.28
Hilu	C. flavovittata	1 - 4	.028	.08
Labroides	Labroides phthirophagus	2 - 3	.024	.07
Band snout	Scarus perspicillatus	3 - 24	32.763	95.14
Sleeping uhu	Calotomus sandvicensis	3 - 15	8.201	23.82
Kihikihi	Zanclus canescens	23 - 5	3.508	10.19

TABLE 17 (continued)

COMMON NAME	SCIENTIFIC NAME	No. fish $\bar{x}$ l. in inches	Weight in Pounds	
			∠ for fish	Per acre
Pakuikui	Acanthurus achilles	31 - 6	5.759	16.72
White-banded maiko	A. leucopareius	15 - 6	2.527	7.34
Maiko	A. nigrofuscus	10 - 5	.813	2.36
	A. nigroris	35 - 4	1.523	4.42
Naenae	A. olivaceus	32 - 8	11.141	32.35
Manini	A. sandvicensis	9 - 5	.945	2.74
Pualu	A. xanthopterus	5 - 8	2.048	5.95
	A. mata	6 - 8	2.304	6.69
Kole	Ctenochaetus strigosus	55 - 5	6.463	18.77
Yellow manini	Zebrasoma flavescens	67 - 5	7.370	21.40
Kala	Naso unicornis	7 - 15	15.120	43.91
	N. lituratus	10 - 8	5.171	15.02
Humuhumu	Balistes bursa	5 - 8 8 - 4	2.734	7.94

TABLE 18. Fish species, number, length and weight observed on transect 2, 6-VI-68, 1208 to 1237 hours. The transect begins at depth 17 feet and ends at depth 15 feet. Accounted for are 44 species and 163.14 pounds of fish per acre.

COMMON NAME	SCIENTIFIC NAME	No. fish $\bar{x}$ l. in inches	Weight in Pounds Σ for fish	Weight in Pounds Per acre
Cornet fish	Fistularia petimba	1 - 24	.276	.40
Trumpet fish	Aulostomus chinensis 3-12"	1 - 18	.661	.96
U'u	Myripristis berndti	3 - 5	.285	.41
Lai	Scomberoides sancti-petri	1 - 18	3.324	4.83
Spot weke	Mulloidichthys samoensis	1 - 8	.246	.36
Malu	Parupeneus pleurostigma	3 - 4	.086	.12
Moano	P. multifasciatus 1-2",	1-8 , 6-4	.479	.70
Potter's angel	Centropyge potteri	11 - 3	.330	.48
Longnose butterfly	Forcipiger longirostris	7 - 4	.211	.31
Blue stripe	Chaetodon fremblii	1 - 4	.061	.09
Cross striped	C. auriga	2 - 5	.273	.40
Orange striped	C. ornatissimus	30 - 4	2.227	3.23
	C. trifasciatus	2 - 4	.131	.19
	C. lunula	2 - 4	.140	.20
	C. unimaculatus	2 - 3	.051	.07
	C. quadrimaculatus	2 - 4	.122	.18
	Chaetodon multicinctus	20 - 4	1.331	1.93
Pilikoa	Paracirrhites arcatus	2 - 4	.093	.14
Maomao	Abudefduf abdominalis	4 - 5 53 - 4	4.203	6.10
Yellow eyedamsel Blue	Pomacentrus jenkinsi	19 - 3 1 - 3	.508	.74
Aloiloi	Dascyllus albisella	1 - 4	.075	.11

TABLE 18 (continued)

COMMON NAME	SCIENTIFIC NAME	No. fish x̄ 1. in inches	Weight in Pounds % for fish	Weight in Pounds Per acre
White tail	Chromis leucurus	55 - 3	1.752	2.54
Black damsel	C. verater	30 - 4	1.862	2.70
Blue damsel	C. ovalis	110 - 2	.739	1.07
Hinalea lauwili	Thalassoma duperreyi	10-5", 62-6	2.985	4.33
Birdfish (hinalea i'iwi)	Gomphosus varius	9-5", 23-4	.831	1.21
Hinalea lolo	Coris gaimardi	2 - 4	.056	.08
Omaka	Stethojulis axillaris	2 - 4	.067	.10
Poou	Cheilinus rhodochrous	1 - 5	.07	.10
Uhu	Scarus dubius	7 - 6	1.134	1.65
Limu teeth	Scarops jordani	2 - 24	20.736	30.11
Kihikihi	Zanclus canescens	13 - 4	1.015	1.47
Pakuikui	Acanthurus achilles	26-6", 38-5	8.915	12.94
White-banded maiko	A. leucopareius	66 - 6	11.120	16.15
Manini	Acanthurus sandvicensis	14 - 4	.753	1.09
Kole	Ctenochaetus strigosus	220 - 4	13.235	19.22
Yellow manini	Zebrasoma flavescens	236 - 4	13.292	19.30
Kala	Naso lituratus	20 - 8	10.342	15.02
Sailfin	Zebrasoma veliferum	4 - 12	6.083	8.83
Humuhumu	Balistes bursa	5 - 5	.556	.81
Oili uwiwi	Pervagor spilosoma	1 - 5	.095	.14
Keke	Arothron hispidus	1 - 12	1.607	2.33
Moa	Ostracion lentiginosus	1 - 2	--	--
Blenny	BLENNIDAE	1 - 4	--	--

TABLE 19. Fish species, number, length and weight observed on transect 2, 13-VIII-68, 1700 to 1740 hours. The transect begins at depth 12 feet and ends at depth 18 feet. Accounted for are 52 species and 204.21 pounds of fish per acre.

COMMON NAME	SCIENTIFIC NAME	No. fish $\bar{x}$ l. in inches	Weight in Pounds	
			Σ for fish	Per acre
Trumpet fish	Aulostomus chinensis	6 - 13	.791	1.15
U'u	Myripristis berndti	10 - 6	1.642	2.38
Kahala	Seriola dumerilii	1 - 15	2.025	2.94
Omilu	Caranx melampygus	1 - 18	3.733	5.42
Spot weke	Mulloidichthys samoensis	1 - 8	.246	.36
Red weke	M. auriflamma	3 - 3	.012	.02
Moano	Parupeneus multifasciatus	1 - 12 9 - 7	2.552	3.71
Moana kea	P. chryserydros	1 - 3	.014	.02
	Monotaxis grandoculis	1 - 7	.192	.28
Potter's angel	Centropyge potteri	6 - 4	.400	.58
Longnose butterfly	Forcipiger longirostris	27 - 4	.812	1.18
Blue stripe	Chaetodon fremblii	7 - 5	.831	1.21
Cross striped	C. auriga	2 - 8	1.116	1.62
Orange striped	C. ornatissimus	15 - 5	2.175	3.16
	C. multicinctus	38 - 5	4.940	7.17
	C. unimaculatus	5 - 5	.594	.86
Pilikoa	Chaetodon quadrimaculatus	4 - 5	.475	.69
Pilikoa	Paracirrhites cinctus	1 - 5	.093	.14
Pilikoa	P. forsteri	2 - 10" 2 - 6	1.702	2.47
Maomao	P. arcatus	2 - 4	.093	.14
	Abudefduf abdominalis	30 - 5	4.050	5.88
	Pomacentrus jenkinsi	37 - 5	4.348	6.31

TABLE 19 (continued)

COMMON NAME	SCIENTIFIC NAME	No. fish x̄ l. in inches	Weight in Pounds for fish	Weight in Pounds Per acre
White tail	Chromis leucurus	92 - 3	2.931	4.26
Black damsel	C. verater	1 - 5	.121	.18
	C. vanderbilti	1 - 4	.042	.06
Hinalea lauwili	Thalassoma duperreyi	87 - 6	9.020	13.10
Birdfish (hinalea i'iwi)	Gomphosus varius	8 - 5	.320	.47
Opule	Anampses cuvieri	5 - 6	.648	.94
Labroides	Labroides phthirophagus	5 - 3	.061	.09
	Novaculichthys taeniourus	3 - 6	.486	.71
Uhu	Scarus dubius 4 - 8"	5 - 12	8.016	11.64
Band snout	S. perspicillatus 1 - 20"	1 - 10	7.110	10.32
Sleeping uhu	Calotomus sandvicensis	1 - 12	1.400	2.03
Kihikihi	Zanclus canescens	15 - 5	2.288	3.32
Surf maiko	Acanthurus guttatus	1 - 5	.156	.23
Pakuikui	A. achilles	10 - 6	1.858	2.70
White-banded maiko	A. leucopareius 18 - 7"	10 - 10	12.616	18.32
Maiko	A. nigroris	115 - 4	5.005	7.27
Naenae	A. olivaceus	10 - 6	1.469	2.13
Manini	A. sandvicensis	13 - 6	2.359	3.43
Palani	A. dussumieri	3 - 12	3.784	5.49
Kole	Ctenochaetus strigosus	165 - 4	9.926	14.41
Hawaiian kole	C. hawaiianensis	1 - 6	.203	.30
Yellow manini	Zebrasoma flavescens	212 - 4	11.940	17.34
Kala	Naso unicornis	1 - 15	2.160	3.14
Kala	N. lituratus 2 - 12"	7 - 8	7.111	10.33

TABLE 19 (continued)

COMMON NAME	SCIENTIFIC NAME	No. fish $\bar{x}$ l. in inches	Weight in Pounds ∠ for fish	Per acre
Humuhumu-ele'ele	Melichthys buniva	19 - 9	15.236	22.12
Humuhumunukunukuapuaa	Rhinecanthus aculeatus	1 - 6	.216	.31
Oili uwiwi	Pervagor spilosoma	2 - 4" 1 - 3	.118	.17
Spotted puffer	Canthigaster jactator	5 - 3	.127	.18
Moa	Ostracion lentiginosus	5 - 3	--	--

TABLE 20. Fish species, number, length and weight observed on transect 2, 29-X-68, 1517 to 1555 hours. The transect begins at depth 20 feet and ends at depth 10 feet. Accounted for are 57 species and 384.55 pounds of fish per acre.

COMMON NAME	SCIENTIFIC NAME	No. fish $\bar{x}$ l. in inches	Weight in Pounds ∠ for fish	Per acre
Eel	Gymnothorax steindachneri	1 - 18	.525	.76
Cornet fish	Fistularia petimba	1 - 18	.117	.17
Trumpet fish	Aulostomus chinensis	3 - 12 2 - 18	1.011	1.47
	Holocentrus sammara	1 - 8	.256	.37
Omilu	Caranx melampygus	1 - 18	3.733	5.42
Gurutsu	Aphareus furcatus	1 - 12	1.037	1.51
Red weke	Mulloidichthys auriflamma	3 - 4	.085	.12
Malu	Parupeneus pleurostigma	13 - 8 8 - 7	4.230	6.14
Manu	P. bifasciatus	8 - 8 7 - 6	2.804	4.07
Moano	P. multifasciatus	8 - 6 2 - 9	1.689	2.45
Moana kea	P. chryserydros	11 - 9	4.250	6.17

TABLE 20 (continued)

COMMON NAME	SCIENTIFIC NAME	No. fish $\bar{x}$ l. in inches	Weight in Pounds ¼ for fish	Weight in Pounds Per acre
Potter's angel	Centropyge potteri	10 - 4	.710	1.03
Longnose butterfly	Forcipiger longirostris	51 - 4	1.534	2.23
Blue stripe	Chaetodon fremblii	4 - 5	.475	.69
Cross striped	C. auriga	9 - 7	3.365	4.89
Orange striped	C. ornatissimus	22 - 6	5.512	8.00
	C. trifasciatus	2 - 4	.131	.19
	C. lunula	13 - 6	3.061	4.45
	C. multicinctus	30 - 4 34 - 4	4.260	6.19
	C. quadrimaculatus	10 - 5	1.188	1.73
	C. unimaculatus	8 - 4	.486	.71
	Hemitaurichthys zoster	1 - 5	.126	.18
Pilikoa	Paracirrhites cinctus	7 - 3	.140	.20
Maomao	Abudefduf abdominalis	10 - 6	2.333	3.39
	Pomacentrus jenkinsi	118 - 4	7.099	10.31
	Chromis dimidiatus	2 - 3	.064	.09
White tail	C. leucurus	10 - 3	.319	.46
Blue damsel	C. ovalis	10 - 3	.227	.33
Hinalea lauwili	Thalassoma duperreyi	24 - 7 35 - 5	6.051	8.79
Birdfish (hinalea i'iwi)	Gomphosus varius	24 - 6	1.659	2.41
Hinalea lolo	Coris gaimardi	10 - 5	.550	.80
Opule	Anampses cuvieri	3 - 7	.617	.90
Labroides	Labroides phthirophagus	1 - 2 1 - 4	.032	.05

TABLE 20 (continued)

COMMON NAME	SCIENTIFIC NAME	No. fish x̄ l. in inches	Weight in Pounds % for fish	Per acre
Omaka	Stethojulis axillaris	3 - 5	.195	.28
Uhu	Scarus dubius	13 - 10	9.750	14.16
Band snout	S. perspicillatus	10 - 10 2 - 18	17.115	24.85
Sleeping uhu	Calotomus sandvicensis	1 - 8	.415	.60
Kihikihi	Zanclus canescens	37 - 5	5.643	8.19
Pakuikui	Acanthurus achilles	79 - 8	34.785	50.51
White-banded maiko	A. leucopareius	68 - 8	27.157	39.43
Maiko	A. nigrofuscus	5 - 4 30 - 4	1.456	2.11
Maiko	A. nigroris	350 - 4 30 - 4	16.538	24.01
Naenae	A. olivaceus	21 - 10	14.280	20.74
Manini	A. sandvicensis	16 - 5 58 - 5	7.770	11.28
Palani	A. dussumieri	53 - 4	2.476	3.60
Pualu	A. xanthopterus	4 - 4	.205	.30
Kole	Ctenochaetus strigosus	224 - 4	13.476	19.57
Yellow manini	Zebrasoma flavescens	215 - 4 143 - 4	20.163	29.28
Kala	Naso unicornis	8 - 8 12 - 8	6.554	9.52
Kala	N. lituratus	14 - 7 5 - 12	13.576	19.71
Humuhumu	Balistes bursa	3 - 4	.171	.25
Humuhumu-uli	Melichthys vidua	1 - 8	.563	.82
Humuhumu-ele'ele	M. buniva	4 - 9 11 - 6	5.822	8.45

TABLE 20 (continued)

COMMON NAME	SCIENTIFIC NAME	No. fish x̄ l. in inches	Weight in Pounds ∠ for fish	Per acre
Humuhumunukunukuapuaa	Rhinecanthus rectangulus	5 - 6	1.091	1.58
Ohua	Amanses sandwichiensis	4 - 7	.947	1.38
Moa	Ostracion lentiginosus	3 - 2	--	--
Lobster	Panulirus penicillatus	1 - 18	5.00	7.26

TABLE 21. Fish species, number, length and weight observed on transect 2, 11-II-69, 1310 to 1345 hours. The transect begins at depth 10 feet and ends at depth 25 feet. Accounted for are 65 species and 547.89 pounds of fish per acre.

COMMON NAME	SCIENTIFIC NAME	No. fish x̄ l. in inches	Weight in Pounds ∠ for fish	Per acre
Lizard fish	Synodus dermatogenys	1 - 12	.553	.80
Trumpet fish	Aulostomus chinensis	3 - 12 3 - 20	1.751	2.54
Alaihi	Holocentrus xantherythrus	6 - 4	.234	.34
	H. diadema	1 - 4	.039	.06
U'u	Myripristis berndti	12 - 6	1.970	2.86
Aweoweo	Priacanthus cruentatus	2 - 6	.242	.35
Gurutsu	Aphareus furcatus	1 - 8	.307	.45
Spot weke	Mulloidichthys samoensis	50 - 7	8.232	11.95
Red weke	M. auriflamma	10 - 7	1.509	2.19
Malu	Parupeneus pleurostigma	1 - 8	.230	.33
Kumu	P. porphyreus	2 - 10	1.140	1.66
Moano	P. multifasciatus	40 - 6	4.579	6.65
Moana kea	P. chryserydros	2 - 8	.543	.79
Mu	Monotaxis grandoculis	1 - 9	.408	.59

TABLE 21 (continued)

COMMON NAME	SCIENTIFIC NAME	No. fish $\bar{x}$ l. in inches	Weight in Pounds ∠ for fish	Weight in Pounds Per acre
Potter's angel	Centropyge potteri	87 - 4	6.181	8.98
Longnose butterfly	Forcipiger longirostris	133 - 4	4.001	5.81
Orange striped	Chaetodon ornatissimus	95 - 6	23.803	34.56
	C. trifasciatus	5 - 4	.326	.47
	C. multicinctus	26 - 4	1.731	2.51
	C. unimaculatus	7 - 4	.426	.62
	C. lunula	7 - 6	1.648	2.39
	C. quadrimaculatus	10 - 4	.608	.88
Pilikoa	Paracirrhites forsteri	1 - 4	.045	.07
	P. arcatus	13 - 4	.607	.88
Maomao	Abudefduf abdominalis	114 - 5	15.390	22.35
	A. imparipennis	21 - 2	.106	.15
	Pomacentrus jenkinsi	136 - 5	15.980	23.20
Aloiloi	Dascyllus albisella	20 - 4	1.498	2.18
White tail	Chromis leucurus	215 - 2	2.038	2.96
Black damsel	C. verater	5 - 4	.310	.45
Blue damsel	C. ovalis	7 - 4	.376	.55
Hinalea lauwili	Thalassoma duperreyi	105 - 5	6.300	9.15
Birdfish (hinalea i'iwi)	Gomphosus varius	65 - 4	1.331	1.93
Hinalea lolo	Coris gaimardi	10 - 6	.950	1.38
Labroides	Labroides phthirophagus	7 - 3	.085	.12
	Novaculichthys taeniourus	6 - 4	.288	.42
Poou	Cheilinus rhodochrous	8 - 8	2.294	3.33
Uhu	Scarus dubius : 5 - 9",	5 -18, 18 - 8	31.516	45.76

TABLE 21 (continued)

COMMON NAME	SCIENTIFIC NAME	No. fish $\bar{x}$ l. in inches	Weight in Pounds Σ for fish	Per acre
	Scarus sordidus	27 - 8	10.368	15.05
	Scarops jordani	3 - 20	18.000	26.14
Kihikihi	Zanclus canescens	38 - 4	2.967	4.31
Surf maiko	Acanthurus guttatus	10 - 6	2.700	3.92
Pakuikui	A. achilles	70 - 4 1 - 8	4.293	6.23
White-banded maiko	A. leucopareius	32 - 6	5.391	7.83
Maiko	A. nigrofuscus	5 - 6	.702	1.02
	A. nigroris	300 - 6	44.064	63.98
Naenae	A. olivaceus	10 - 10	6.800	9.87
Manini	A. sandvicensis	136 - 4	7.311	10.62
Palani	A. dussumieri	28 - 8	10.465	15.20
Pualu	A. mata	71 - 4	3.408	4.95
Kole	Ctenochaetus strigosus	225 - 4	13.536	19.65
Yellow manini	Zebrasoma flavescens	425 - 4	23.936	34.76
Sailfin tang	Z. veliferum	1 - 6	.190	.28
Kala	Naso hexacanthus	77 - 8	21.289	30.91
	N. unicornis	2 - 12	2.212	3.21
	N. lituratus	79 - 7	27.368	39.74
Humuhumu	Balistes bursa	9 - 6	1.730	2.51
Humuhumi-mimi	B. capistratus	2 - 7	.679	.99
Humuhumu-uli	Melichthys vidua	1 - 5	.138	.20
Loulu	Alutera monoceros	2 - 12	2.385	3.46
Oili uwiwi	Pervagor spilosoma	5 - 4	.243	.35

TABLE 21 (continued)

COMMON NAME	SCIENTIFIC NAME	No. fish $\bar{x}$ l. in inches	Weight in Pounds	
			Σ for fish	Per acre
Moa	Ostracion lentiginosus	3 - 2	--*	--*
Spotted puffer	Canthigaster jactator	1 - 3	.025	.04
Nenue	Kyphosus cinerescens	2 - 12	2.557	3.71
Turtle	Chelonia mydas	1 - 18	25.00	36.30

TABLE 22. Fish species, number, length and weight observed on transect 3, 13-VIII-68, 1140 to 1215 hours. The transect begins at depth 10 feet and ends at depth 10 feet. Accounted for are 39 species and 101.93 pounds of fish per acre.

COMMON NAME	SCIENTIFIC NAME	No. fish $\bar{x}$ l. in inches	Weight in Pounds £ for fish	Weight in Pounds Per acre
Trumpet fish	Aulostomus chinensis	2 - 12	.207	.30
U'u	Myripristis berndti	1 - 4	.049	.07
Spot weke	Mulloidichthys samoensis	12 - 7	1.976	2.87
Red weke	M. auriflamma	10 - 5	.550	.80
Malu	Parupeneus pleurostigma	1 - 6	.097	.14
Moano	P. multifasciatus 3 - 7"	2 - 4	.613	.89
Moana kea	P. chryserydros	1 - 12	.916	1.33
Potter's angel	Centropyge potteri	1 - 4	.071	.10
Longnose butterfly	Forcipiger longirostris	5 - 5	.294	.43
Blue stripe	Chaetodon fremblii	2 - 5	.238	.35
Orange striped	C. ornatissimus	13 - 5	1.885	2.74
	C. lunula	1 - 8	.558	.81
	C. multicinctus	25 - 4	1.664	2.42
	C. quadrimaculatus	3 - 5	.356	.52
Pilikoa	Paracirrhites arcatus	2 - 4	.093	.14
Maomao	Abudefduf abdominalis	5 - 5	.675	.98
	Pomacentrus jenkinsi	27 - 4	1.624	2.36
White tail	Chromis leucurus	5 - 3	.159	.23
Hinalea lauwili	Thalassoma duperreyi	71 - 6 4 - 4	7.484	10.87
Birdfish (hinalea i'iwi)	Gomphosus varius	3 - 5	.120	.17
Hinalea lolo	Coris gaimardi	1 - 5	.055	.08

TABLE 22 (continued)

COMMON NAME	SCIENTIFIC NAME	No. fish $\bar{x}$ l. in inches	Weight in Pounds ≤ for fish	Per acre
Omaka	Stethojulis axillaris	3 - 4	.100	.15
Uhu	Scarus dubius 4 - 5"	1 - 8	.759	1.10
Band snout	S. perspicillatus	1 - 18	4.607	6.69
Kihikihi	Zanclus canescens	3 - 5	.458	.67
Pakuikui	Acanthurus achilles	29 - 6	5.387	7.82
White-banded maiko	A. leucopareius	24 - 8	9.585	13.92
Maiko	A. nigroris	38 - 4	1.654	2.40
Naenae	A. olivaceus	21 - 5	1.785	2.59
Manini	A. sandvicensis	5 - 6	.907	1.32
Palani	A. dussumieri	1 - 8	.374	.54
Pualu	A. mata	31 - 5	2.906	4.22
Kole	Ctenochaetus strigosus	104 - 4	6.257	9.09
Yellow manini	Zebrasoma flavescens	92 - 5	10.120	14.69
Kala	Naso lituratus	18 - 6	3.927	5.70
Humuhumu	Balistes bursa	4 - 6	.769	1.12
Humuhumu-ele'ele	Melichthys buniva	1 - 8	.563	.82
Humuhumunukunukuapuaa	Rhinecanthus rectangulus	1 - 6	.218	.32
Spotted puffer	Canthigaster jactator	2 - 4	.120	.17

TABLE 23. Fish species, number, length and weight observed on transect 3, 29-X-68, 1645 to 1730 hours. The transect begins at depth 10 feet and ends at depth 14 feet. Accounted for are 63 species and 669.08 pounds of fish per acre.

COMMON NAME	SCIENTIFIC NAME	No. fish $\bar{x}$ l. in inches	Weight in Pounds ∠ for fish	Per acre
Trumpet fish	Aulostomus chinensis	1 - 20 1 - 9	.524	.76
Alaihi	Holocentrus xantherythrus	1 - 3	.017	.03
U'u	Myripristis berndti	8 - 6	1.313	1.91
Upapalu	Apogon snyderi	3 - 4	.121	.18
White ulua	Carangoides ajax	30 - 24	265.421	385.39
Spot weke	Mulloidichthys samoensis	16 - 10 5 - 6	8.198	11.90
Red weke	M. auriflamma	8 - 4	.225	.33
Malu	Parupeneus pleurostigma	3 - 5	.169	.25
Kumu	P. porphyreus	4 - 6	.493	.72
Moano	P. multifasciatus	14 - 7	2.545	3.70
Moana kea	P. chryserydros	7 - 6	.801	1.16
Potter's angel	Centropyge potteri	16 - 4	1.137	1.65
Longnose butterfly	Forcipiger longirostris	22 - 4 10 - 5	1.248	1.81
Blue stripe	Chaetodon fremblii	17 - 5	2.019	2.93
Orange striped	C. ornatissimus	18 - 6	4.510	6.55
Puka	Chaetodon miliaris	1 - 4	.060	.09
	C. trifasciatus	2 - 6	.441	.64
	C. multicinctus	48 - 4	3.195	4.64
	C. unimaculatus	4 - 3	.103	.15

TABLE 23 (continued)

COMMON NAME	SCIENTIFIC NAME	No. fish x̄ l. in inches	Weight in Pounds ¼ for fish	Per acre
	C. lunula	7 - 8 2 - 6	4.378	6.36
	C. quadrimaculatus	8 - 4	.486	.71
	Hemitaurichthys zoster	1 - 5	.126	.18
Pilikoa	Paracirrhites cinctus	7 - 4	.332	.48
Pilikoa	P. forsteri	1 - 4 3 - 8	1.120	1.63
Pilikoa	P. arcatus	3 - 4	.140	.20
Poo-paa	Cirrhitus alternatus	2 - 8	.819	1.19
Maomao	Abudefduf abdominalis	5 - 4	.346	.50
Kupipi	A. sordidus	4 - 6	.544	.79
	Pomacentrus jenkinsi	23 - 5 15 - 4	3.605	5.24
	Chromis dimidiatus	1 - 3	.032	.05
White tail	C. leucurus	21 - 3	.669	.97
Hinalea lauwili	Thalassoma duperreyi	90 - 6	9.331	13.55
	T. umbrostigma	3 - 5	.195	.28
Birdfish (hinalea i'iwi)	Gomphosus varius	19 - 8	.760	1.10
Hinalea lolo	Coris gaimardi	13 - 4	.366	.53
Labroides	Labroides phthirophagus	7 - 3	.085	.12
	Novaculichthys taeniourus	1 - 6	.162	.24
Omaka	Stethojulis axillaris	16 - 5 1 - 9	1.419	2.06

TABLE 23 (continued)

COMMON NAME	SCIENTIFIC NAME	No. fish $\bar{x}$ l. in inches	Weight in Pounds Σ for fish	Per acre
Uhu	Scarus dubius	2 - 18 5 - 8 20 - 5	12.543	18.21
Band snout	S. perspicillatus	3 - 15 1 - 20	14.319	20.79
Kihikihi	Zanclus canescens	27 - 5	4.118	5.98
Pakuikui	Acanthurus achilles	76 - 5	8.170	11.86
White-banded maiko	A. leucopareius	145 - 5	14.138	20.53
Maiko	A. nigrofuscus	78 - 4	3.245	4.71
Naenae	A. olivaceus	9 - 6	1.322	1.92
Manini	A. sandvicensis	22 - 4	1.183	1.72
Palani	A. dussumieri	3 - 15	7.391	10.73
Pualu	A. xanthopterus	52 - 6	8.986	13.05
Kole	Ctenochaetus strigosus	175 - 5	20.563	29.86
Hawaiian kole	C. hawaiiensis	1 - 4	.060	.09
Yellow manini	Zebrasoma flavescens	141 - 4	7.941	11.53
Horned kala	Naso brevirostris	1 - 10 2 - 6	1.002	1.46
Kala	N. lituratus	47 - 6	10.254	14.89
Humuhumu-uli	Melichthys vidua	3 - 6	.713	1.04
Humuhumu-ele'ele	M. buniva	4 - 5	.550	.80
	Xanthichthys ringens	1 - 3	.108	.16
Humuhumunukunu-kuapuaa	Rhinecanthus rectangulus	6 - 6 1 - 1	1.309	1.90
Oili uwiwi	Pervagor spilosoma	7 - 4	.341	.50
Moa	Ostracion lentiginosus	3 - 3	--	--
Spotted puffer	Canthigaster jactator	1 - 2	.008	.01

TABLE 23 (continued)

COMMON NAME	SCIENTIFIC NAME	No. fish $\bar{x}$ l. in inches	Weight in Pounds Σ for fish	Per acre
Blenny	Cirripectus obscurus	2 - 5 1 - 8	--	--
Moi	Polydactylus sexfilis	25 - 12	25.00	36.30
Lion fish	Pterois sphex	1 - 4	.047	.07

TABLE 24. Fish species, number, length and weight observed on transect 3, 11-II-69, 1154 to 1227 hours. The transect begins at depth 16 feet and ends at depth 16 feet. Accounted for are 46 species and 166.81 pounds of fish per acre.

COMMON NAME	SCIENTIFIC NAME	No. fish $\bar{x}$ l. in inches	Weight in Pounds Σ for fish	Per acre
Trumpet fish	Aulostomus chinensis	3 - 15 2 - 30	3.848	5.59
Alaihi	Holocentrus spinifer	2 - 10	1.740	2.53
	H. scythrops	8 - 6	1.071	1.56
U'u	Myripristis berndti	16 - 6	2.627	3.81
Aweoweo	Priacanthus cruentatus	9 - 9	3.674	5.34
Spot weke	Mulloidichthys samoensis	17 - 6	1.763	2.56
Red weke	M. auriflamma	13 - 6	1.236	1.80
Kumu	Parupeneus porphyreus	3 - 5	.214	.31
Manu	P. bifasciatus	2 - 8	.512	.74
Moano	P. multifasciatus	9 - 5 9 - 8 2 - 10	4.098	5.95
Black-white angel	Holacanthus arcuatus	1 - 5	.139	.20
Potter's angel	Centropyge potteri	30 - 4	2.131	4.55
Longnose butterfly	Forcipiger longirostris	43 - 5	2.526	3.67

TABLE 24 (continued)

COMMON NAME	SCIENTIFIC NAME	No. fish x̄ l. in inches	Weight in Pounds Σ for fish	Per acre
Cross striped	Chaetodon auriga	2 - 6	.471	.68
Orange striped	C. ornatissimus	27 - 7	10.743	15.60
Puka	C. multicinctus	24 - 4	1.597	2.32
	C. lunula	3 - 6	.706	1.03
Pilikoa	Paracirrhites cinctus	1 - 4	.047	.07
	P. forsteri	1 - 6	.240	.35
	P. arcatus	12 - 4 1 - 7	.811	1.18
Poo-paa	Cirrhitus alternatus	1 - 5	.100	.15
Maomao	Abudefduf abdominalis	7 - 5	.945	1.37
	Pomacentrus jenkinsi	32 - 5	3.760	5.46
Aloiloi	Dascyllus albisella	10 - 5	1.463	2.12
White tail	Chromis leucurus	36 - 3	1.147	1.67
Blue damsel	C. ovalis	30 - 2	.202	.29
Hinalea lauwili	Thalassoma duperreyi	50 - 4	1.536	2.23
Birdfish (hinalea i'iwi)	Gomphosus varius	8 - 4	.164	.24
Hinalea lolo	Coris gaimardi	18 - 5	.990	1.44
Labroides	Labroides phthirophagus	22 - 3	.267	.39
Uhu	Scarus dubius	17 - 4	.816	1.19
Band snout	S. perspicillatus	6 - 12	8.191	11.89
Kihikihi	Zanclus canescens	23 - 5	3.508	5.09
Pakuikui	Acanthurus achilles	3 - 5	.323	.47
White-banded maiko	A. leucopareius	19 - 8	7.588	11.02
Maiko	A. nigroris	12 - 5	1.020	1.48

TABLE 24 (continued)

COMMON NAME	SCIENTIFIC NAME	No. fish $\bar{x}$ l. in inches	Weight in Pounds ∠ for fish	Per acre
Naenae	A. olivaceus	23 - 8	8.008	11.63
Palani	A. dussumieri	10 - 8	3.738	5.43
Pualu	Acanthurus xanthopterus	4 - 6	.691	1.00
	A. mata	23 - 5	2.156	3.13
Kole	Ctenochaetus strigosus	72 - 5	8.460	12.28
Yellow manini	Zebrasoma flavescens	101 - 5	11.110	16.13
Sailfin tang	Z. veliferum	1 - 6	.190	.28
Kala	Naso lituratus	12 - 7	4.157	6.04
Humuhumu	Balistes bursa	14 - 6	2.691	3.91
Oili uwiwi	Pervagor spilosoma	9 - 4	.438	.64

Note: About 20 toau (Lutjanus vaigiensis) observed under coral heads past the end of the transect line.

TABLE 25. Fish species, number, length and weight observed on transect 4, 6-VI-68, 1538 to 1600 hours. The transect begins at depth 55 feet and ends at depth 23 feet. Accounted for are 41 species and 174.89 pounds of fish per acre.

COMMON NAME	SCIENTIFIC NAME	No. fish x̄ l. in inches	Weight in Pounds ∑ for fish	Weight in Pounds Per acre
Alaihi	Holocentrus xantherythrus	1 - 5	.076	.11
U'u	Myripristis berndti	1 - 3	.021	.03
Uku	Aprion virescens 1-36"	1 - 12	29.031	42.15
Spot weke	Mulloidichthys samoensis	15 - 8	3.686	5.35
Malu	Parupeneus pleurostigma	2-8", 4-6	.850	1.23
Moano	P. multifasciatus	11 - 6	1.259	1.83
Moana kea	P. chryserydros	1 - 6	.114	.17
	Monotaxis grandoculis 1-8",	1-12	1.255	1.82
Potter's angel	Centropyge potteri	9 - 3	.270	.39
Longnose butterfly	Forcipiger longirostris	8 - 4	.241	.35
Blue stripe	Chaetodon fremblii	1 - 6	.205	.30
Cross striped	C. auriga	1 - 5	.136	.20
Orange striped	C. ornatissimus	17 - 4	1.262	1.83
	C. multicinctus	5 - 4	.33	.48
Poo-paa	Cirrhitus alternatus	2 - 6	.346	.50
Maomao	Abudefduf abdominalis	15 - 4	1.037	1.51
Yellow eye damsel	Pomacentrus jenkinsi	9 - 3	.228	.33
Aloiloi	Dascyllus albisella	65 - 4	4.867	7.07
White tail	Chromis leucurus	32 - 2	.302	.44
Black damsel	C. verater	24 - 5	2.910	4.23
Hinalea lauwili	Thalassoma duperreyi	24 - 4	.737	1.07

TABLE 25 (continued)

COMMON NAME	SCIENTIFIC NAME	No. fish x̄ l. in inches	Weight in Pounds £ for fish	Per acre
Birdfish (hinalea i'iwi)	Gomphosus varius	8 - 4	.164	.24
Hinalea lolo	Coris gaimardi 3 - 6",	2 - 4	.341	.50
	Novaculichthys taeniourus	1 - 8	.384	..56
Omaka	Stethojulis axillaris	4 - 4	.133	.19
Poou	Cheilinus rhodochrous	2 - 4	.072	.10
Uhu	Scarus dubius	24 - 8	9.216	13.38
Band snout	S. perspicillatus	1 - 18	4.607	6.69
	S. sordidus	1 - 12	1.296	1.88
Fuji's Limuteeth	Scarops jordani	3 - 24	31.104	45.16
Kihikihi	Zanclus canescens	11 - 4	.859	1.25
Naenae	Acanthurus olivaceus	9 - 8	3.133	4.55
Palani	A. dussumieri	1 - 8	.374	.54
Kole	Ctenochaetus strigosus	78 - 4	4.692	6.81
Yellow manini	Zebrasoma flavescens	109 - 4	6.139	8.91
Kala	Naso lituratus 6-10", 4-3 , 5-5		6.800	9.87
Kole	Ctenochaetus hawaiianensis	2 - 4	.120	.17
Black	Acanthurus thompsonii	2 - 6	.246	.36
	Zebrasoma veliferum	14 - 3	.333	.48
Humuhumu	Balistes bursa 5-5", 1-6", 6-3		.892	1.30
Oili uwiwi	Pervagor spilosoma	8 - 4	.389	.56

TABLE 26. Fish species, number, length and weight observed on transect 4, 13-VIII-68, 0857 to 0915 hours. The transect begins at depth 53 feet and ends at depth 27 feet. Accounted for are 43 species and 102.36 pounds of fish per acre.

COMMON NAME	SCIENTIFIC NAME	No. fish $\bar{x}$ l. in inches	Weight in Pounds ½ for fish	Per acre
Puhi paka	Gymnothorax flavimarginatus	1 - 36	4.199	6.10
Trumpet fish	Aulostomus chinensis	5 - 8	.154	.22
	Holocentrus ensifer	1 - 8	.312	.45
U'u	Myripristis berndti	6 - 10	4.560	6.62
Upapalu	Apogon snyderi	2 - 6	.272	.40
Spot weke	Mulloidichthys samoensis	6 - 6	.622	.90
Red weke	M. auriflamma	2 - 4	.056	.08
Malu	Parupeneus pleurostigma	4 - 6	.389	.57
Manu	P. bifasciatus	2 - 6	.216	.31
Moano	P. multifasciatus	7 - 6	.801	1.16
Black-white angel	Holacanthus arcuatus	1 - 4	.071	.10
Potter's angel	Centropyge potteri	22 - 3	.659	.96
Longnose butterfly	Forcipiger longirostris	20 - 4	.602	.87
Orange striped	Chaetodon ornatissimus	22 - 4	1.633	2.37
	C. lunula	2 - 4	.140	.20
	C. multicinctus	29 - 5	3.770	5.47
	Pomacentrus jenkinsi	5 - 4	.301	.44
Aloiloi	Dascyllus albisella	55 - 4	4.118	5.98
White tail	Chromis leucurus	27 - 3	.860	1.25
Black damsel	C. verater	10 - 4	.621	.90
Blue damsel	C. ovalis	6 - 3	.136	.20

TABLE 26 (continued)

COMMON NAME	SCIENTIFIC NAME	No. fish $\bar{x}$ l. in inches	Weight in Pounds $\leq$ for fish	Per acre
Hinalea lauwili	Thalassoma duperreyi	58 - 5	3.480	5.05
Hinalea luahine	T. ballieui	13 - 4	.499	.73
Hinalea lolo	Coris gaimardi	13 - 6	1.236	1.80
Opule	Anampses cuvieri	4 - 4	.154	.22
Labroides	Labroides phthirophagus	2 - 4	.058	.08
Omaka	Stethojulis axillaris	3 - 4	.100	.15
Poou	Cheilinus rhodochrous	2 - 6	.242	.35
Uhu	Scarus dubius 14 - 8"	12 - 6	7.320	10.63
	S. sordidus	1 - 12	1.296	1.88
Kihikihi	Zanclus canescens	8 - 4	.625	.91
Pakuikui	Acanthurus achilles	2 - 4	.110	.16
White-banded maiko	A. leucopareius	2 - 6	.337	.49
Maiko	A. nigrofuscus	10 - 4	.416	.60
Maiko	A. nigroris	10 - 3	.184	.27
Naenae	A. olivaceus	34 - 8	11.837	17.19
Palani	A. dussumieri	3 - 8	1.121	1.63
Kole	Ctenochaetus strigosus	115 - 4	6.918	10.05
Yellow manini	Zebrasoma flavescens	154 - 4	8.673	12.59
Kala	Naso lituratus	1 - 6	.218	.32
Humuhumu	Balistes bursa	18 - 4	1.025	1.49
Oili uwiwi	Pervagor spilosoma	1 - 3	.021	.03
Banded puffer	Canthigaster cinctus	1 - 5	.130	.19

TABLE 27. Fish species, number, length and weight observed on transect 4, 29-X-68, 1320 to 1350 hours. The transect begins at depth 55 feet and ends at depth 22 feet. Accounted for are 43 species and 107.23 pounds of fish per acre.

COMMON NAME	SCIENTIFIC NAME	No. fish $\bar{x}$ l. in inches	Weight in Pounds Σ for fish	Per acre
Lizard fish	Synodous variegatus	3 - 8	.492	.71
Trumpet fish	Aulostomus chinensis	2 - 10 4 - 8	.243	.35
	Holocentrus sammara	1 - 10	.500	.73
Uku	Aprion virescens	1 - 8 1 - 14	1.953	2.84
Spot weke	Mulloidichthys samoensis	6 - 5 1 - 8	.606	.88
Malu	Parupeneus pleurostigma	3 - 7	.154	.22
Manu	P. bifasciatus	1 - 8	.256	.37
Moano	P. multifasciatus	6 - 6	.687	1.00
Moana kea	P. chryserydros	6 - 5	.398	.58
Mu	Monotaxis grandoculis	3 - 6	.363	.53
Potter's angel	Centropyge potteri	7 - 4	.497	.72
Longnose butterfly	Forcipiger longirostris	10 - 4	.301	.44
Corallicola	Chaetodon corallicola	8 - 3	.212	.31
Cross striped	C. auriga	1 - 6	.235	.34
Orange striped	C. ornatissimus	6 - 6	1.503	2.18
	C. unimaculatus	1 - 4	.061	.09
	C. multicinctus	9 - 4	.599	.87
Pilikoa	Paracirrhites forsteri	1 - 10	.700	1.02

TABLE 27 (continued)

COMMON NAME	SCIENTIFIC NAME	No. fish $\bar{x}$ l. in inches	Weight in Pounds Σ for fish	Per acre
Maomao	Abudefduf abdominalis	9 - 6	2.100	3.05
	Pomacentrus jenkinsi	1 - 5	.118	.17
Aloiloi	Dascyllus albisella	100 - 4	7.488	10.87
White tail	Chromis leucurus	80 - 3	2.549	3.70
Black damsel	C. verater	27 - 5	3.274	4.75
A'awa	Bodianus bilunulatus	2 - 7 1 - 3	.585	.85
Hinalea lauwili	Thalassoma duperreyi	25 - 7	1.500	2.18
Birdfish (hinalea i'iwi)	Gomphosus varius	5 - 3	.043	.06
Hinalea lolo	Coris gaimardi	18 - 6	1.711	2.48
Labroides	Labroides phthirophagus	1 - 2	.004	.01
	Novaculichthys taeniourus	1 - 4	.048	.07
Uhu	Scarus dubius	9 - 6 23 - 8	10.290	14.94
Band snout	S. perspicillatus	1 - 8 3 - 10	7.382	10.72
	S. formosus	1 - 10	.750	1.09
Sleeping uhu	Calotomus sandvicensis	1 - 8	.415	.60
Kihikihi	Zanclus canescens	16 - 4	.768	1.12
Maiko	Acanthurus nigrofuscus	23 - 4	.957	1.39
Naenae	A. olivaceus	4 - 6 3 - 8	1.633	2.37
Pualu	A. xanthopterus	5 - 4	.256	.37
Kole	Ctenochaetus strigosus	103 - 4	6.197	9.00
Yellow manini	Zebrasoma flavescens	110 - 5	12.100	17.57

TABLE 27 (continued)

COMMON NAME	SCIENTIFIC NAME	No. fish $\bar{x}$ l. in inches	Weight in Pounds Σ for fish	Per acre
Kala	Naso lituratus	5 - 8 1 - 5	2.712	3.94
Humuhumu	Balistes bursa	6 - 4	.342	.50
Humuhumu-uli	Melichthys vidua	4 - 6	.713	1.04
Oili uwiwi	Pervagor spilosoma	3 - 4	.146	.21

TABLE 28. Fish species, number, length and weight observed on transect 4, 12-II-69, 1254 to 1315 hours. The transect begins at depth 56 feet and ends at depth 32 feet. Accounted for are 47 species and 201.24 pounds of fish per acre.

COMMON NAME	SCIENTIFIC NAME	No. fish $\bar{x}$ l. in inches	Weight in Pounds Σ for fish	Per acre
Trumpet fish	Aulostomus chinensis	3 - 12	.311	.45
U'u	Myripristis berndti	3 - 8	1.167	1.70
Spot weke	Mulloidichthys samoensis	43 - 8	10.568	15.35
Malu	Parupeneus pleurostigma	3 - 6	.292	.42
Manu	P. bifasciatus	1 - 6	.108	.16
Moano	P. multifasciatus	18 - 8	4.885	7.09
Potter's angel	Centropyge potteri	21 - 4	1.492	2.17
Longnose butterfly	Forcipiger longirostris	24 - 5	1.410	2.05
Cross striped	Chaetodon auriga	3 - 6	.706	1.03
Orange striped	C. ornatissimus	10 - 6	2.506	3.64
	C. multicinctus	48 - 4	3.195	4.64
	C. unimaculatus	2 - 4	.122	.18
	C. lunula	8 - 6	1.884	2.74

TABLE 28 (continued)

COMMON NAME	SCIENTIFIC NAME	No. fish x̄ l. in inches	Weight in Pounds ∠ for fish	Weight in Pounds Per acre
	Hemitaurichthys zoster	1 - 4	.065	.09
	Paracirrhites forsteri	5 - 8	1.792	2.60
Pilikoa	P. arcatus	5 - 4	.234	.34
Maomao	Abudefduf abdominalis	10 - 5	1.350	1.96
[illegible]	Pomacentrus jenkinsi	1 - 4	.060	.09
Aloiloi	Dascyllus albisella	34 - 4	2.546	3.70
White tail	Chromis leucurus	37 - 3	1.179	1.71
Black damsel	C. verater	6 - 6	1.257	1.83
Blue damsel	C. ovalis	4 - 3	.091	.13
A'awa	Bodianus bilunulatus	5 - 11	4.525	6.57
Hinalea lauwili	Thalassoma duperreyi	66 - 5	3.960	5.75
Hinalea luahine	T. ballieui	2 - 8	.614	.89
Birdfish (hinalea i'iwi)	Gomphosus varius	2 - 4	.041	.06
Hinalea lolo	Coris gaimardi	20 - 6	1.901	2.76
Labroides	Labroides phthirophagus	9 - 3	.109	.16
	Novaculichthys taeniourus	1 - 4	.048	.07
Poou	Cheilinus rhodochrous	8 - 9	3.266	4.74
Uhu	Scarus dubius	41 - 6	6.642	9.64
Band snout	S. perspicillatus	5 - 18 1 - 24	33.957	49.31
	S. sordidus	4 - 6	.648	.94
Sleeping uhu	Calotomus sandvicensis	1 - 6	.175	.25
Kihikihi	Zanclus canescens	24 - 5	3.660	5.31
Pakuikui	Acanthurus achilles	10 - 6	1.858	2.70

TABLE 28 (continued)

COMMON NAME	SCIENTIFIC NAME	No. fish $\bar{x}$ l. in inches	Weight in Pounds Σ for fish	Per acre
Maiko	A. nigrofuscus	2 - 5	.163	.24
	A. nigroris	4 - 5	.340	.49
	A. olivaceus	27 - 10	18.360	26.66
Manini	A. sandvicensis	2 - 5	.210	.31
Pualu	Acanthurus mata	9 - 4	.432	.63
Kole	Ctenochaetus strigosus	85 - 4	5.114	7.43
Yellow manini	Zebrasoma flavescens	96 - 4	5.407	7.85
Kala	Naso lituratus	7 - 8	3.620	5.26
Humuhumu	Balistes bursa	20 - 7 2 - 4	6.219	9.03
	Xanthichthys ringens	1 - 6	.064	.09
Oili uwiwi	Pervagor spilosoma	1 - 3	.021	.03

TABLE 29. Fish species, number, length and weight observed on transect 5, 6-VI-68, 0905 to 0935 hours. The transect begins at depth 60 feet and ends at depth 20 feet. Accounted for are 38 species and 110.47 pounds of fish per acre.

COMMON NAME	SCIENTIFIC NAME	No. fish $\bar{x}$ l. in inches	Weight in Pounds Σ for fish	Per acre
	Holocentrus ensifer	1 - 6	.132	.24
Moano	Parupeneus multifasciatus	6 - 6	.687	1.25
Potter's angel	Centropyge potteri	15 - 4	1.066	1.93
Longnose butterfly	Forcipiger longirostris	18 - 4	.541	.98
Blue stripe	Chaetodon fremblii	1 - 4	.061	.11
Orange striped	C. ornatissimus	16 - 4	1.188	2.16
	C. lunula	1 - 5	.136	.25
	C. multicinctus	10 - 4	.666	1.21
Pilikoa	Paracirrhites forsteri	1 - 5	.088	.16
Yellow eye damse:	Pomacentrus jenkinsi	6 - 3	.152	.28
White tail	Chromis leucurus	67 - 3	2.135	3.88
Black damsel	C. verater	37 - 5	4.486	8.14
Hinalea lauwili	Thalassoma duperreyi	27 - 4	.829	1.50
Hinalea luahine	T. ballieui	4 - 4	.154	.28
Birdfish (hinalea i'iwi)	Gomphosus varius 1 - 2"	2 - 5	.083	.15
Hinalea lolo	Coris gaimardi	2 - 5	.110	.20
Hilu	Coris flavovittata	1 - 2	.003	.01
Labroides	Labroides phthirophagus	1 - 3	.012	.02
Omaka	Stethojulis axillaris	2 - 4	.067	.12
Poou	Cheilinus rhodochrous	4 - 10	2.240	4.07
	Pseudocheilinus octotaenia	1 - 4	.035	.06

TABLE 29 (continued)

COMMON NAME	SCIENTIFIC NAME	No. fish $\bar{x}$ l. in inches	Weight in Pounds	
			∠ for fish	Per acre
	Thalassoma lutecens	1 - 4	.031	.06
Uhu	Scarus dubius	2 - 6	.324	.59
Band snout	S. perspicillatus	1 - 18	4.607	8.36
	S. sordidus	4 - 6	.648	1.18
Limu teeth	Scarops jordani	10 - 12	12.960	23.52
Kihikihi	Zanclus canescens	16 - 5	2.440	4.43
Pakuikui	Acanthurus achilles	2 - 6	.372	.68
Maiko	A. nigroris	5 - 4	.218	.40
Naenae	A. olivaceus	1 - 10	.680	1.23
Palani	A. dussumieri	1 - 12	1.261	2.29
Pualu	A. xanthopterus	2 - 4	.102	.19
Kole	Ctenochaetus strigosus	194 - 4	11.671	21.18
Yellow manini	Zebrasoma flavescens	130 - 4	7.322	13.29
Kala	Naso lituratus	8 - 6	1.745	3.17
Kole	Ctenochaetus hawaiianensis	1 - 4	.060	.11
Humuhumu	Balistes bursa	13 - 5	1.446	2.62
Oili uwiwi	Pervagor spilosoma	1 - 5	.095	.17

TABLE 30. Fish species, number, length and weight observed on transect 5, 13-VIII-68, 1600 to 1644 hours. The transect begins at depth 70 feet and ends at depth 20 feet. Accounted for are 34 species and 58.19 pounds of fish per acre.

COMMON NAME	SCIENTIFIC NAME	No. fish x̄ l. in inches	Weight in Pounds Σ for fish	Per acre
Trumpet fish	Aulostomus chinensis	2 - 6	.026	.04
Spot weke	Mulloidichthys samoensis	2 - 8	.492	.71
Manu	Parupeneus bifasciatus	1 - 6	.108	.16
Moano	P. multifasciatus 1 - 8"	1 - 6	.386	.56
Potter's angel	Centropyge potteri	21 - 4	1.492	2.17
Longnose butterfly	Forcipiger longirostris	11 - 4	.331	.48
Orange striped	Chaetodon ornatissimus	12 - 4	.891	1.29
	C. lunula	1 - 6	.235	.34
	C. multicinctus	13 - 4	.865	1.26
Pilikoa	Paracirrhites cinctus	1 - 6	.160	.23
Pilikoa	P. forsteri	1 - 6	.151	.22
	Pomacentrus jenkinsi	9 - 4	.541	.79
White tail	Chromis leucurus	61 - 3	1.944	2.82
Black damsel	C. verater	1 - 5	.121	.18
Blue damsel	C. ovalis	12 - 3	.272	.40
Hinalea lauwili	Thalassoma duperreyi	30 - 4	.922	1.34
Hinalea lolo	Coris gaimardi	3 - 8	.676	.98
	Novaculichthys taeniourus	1 - 6	.162	.24
Ohua	Stethojulis albovittata	2 - 4	.069	.10
Omaka	S. axillaris	3 - 4	.100	.15
Poou	Cheilinus rhodochrous	6 - 6	.726	1.05

TABLE 30 (continued)

COMMON NAME	SCIENTIFIC NAME	No. fish $\bar{x}$ l. in inches	Weight in Pounds ∠ for fish	Per acre
Uhu	Scarus dubius 15 - 6"	10 - 4	2.910	4.23
Band snout	S. perspicillatus	1 - 12	1.365	1.98
Kihikihi	Zanclus canescens	6 - 6	2.108	3.06
Maiko	Acanthurus nigrofuscus	5 - 4	.208	.30
Maiko	A. nigroris	18 - 4	.783	1.14
Naenae	A. olivaceus	6 - 10	4.080	5.92
Kole	Ctenochaetus strigosus	166 - 4	9.987	14.50
Hawaiian kole	C. hawaiianensis	1 - 4	.060	.09
Yellow manini	Zebrasoma flavescens	89 - 4	5.013	7.41
Kala	Naso lituratus	2 - 8	1.034	1.50
Humuhumu	Balistes bursa	15 - 5	1.669	2.42
Humuhumu-uli	Melichthys vidua	1 - 4	.070	.10
Oili uwiwi	Pervagor spilosoma	1 - 3	.021	.03

TABLE 31. Fish species, number, length and weight observed on transect 5, 30-X-68, 1040 to 1101 hours. The transect begins at depth 75 feet and ends at depth 22 feet. Accounted for are 40 species and 162.71 pounds of fish per acre.

COMMON NAME	SCIENTIFIC NAME	No. fish $\bar{x}$ l. in inches	Weight in Pounds ∠ for fish	Per acre
Trumpet fish	Aulostomus chinensis	1 - 7	.021	.03
U'u	Myripristis berndti	1 - 7	.261	.38
Gurutsu	Aphareus furcatus	1 - 7	.206	.30
Moano	Parupeneus multifasciatus	16 - 6	1.832	2.66
Mu	Monotaxis grandoculis	1 - 12	.968	1.41
Potter's angel	Centropyge potteri	13 - 4	.924	1.34

TABLE 31 (continued)

COMMON NAME	SCIENTIFIC NAME	No. fish x̄ l. in inches	Weight in Pounds ∑ for fish	Per acre
Longnose butterfly	Forcipiger longirostris	16 - 4	.481	.70
Orange striped	Chaetodon ornatissimus	8 - 6	2.005	2.91
	C. lunula	2 - 6	.471	.68
	C. multicinctus	27 - 4	1.797	2.61
	C. quadrimaculatus	2 - 4	.122	.18
Pilikoa	Paracirrhites forsteri	1 - 8	.358	.52
Maomao	Abudefduf abdominalis	6 - 6	1.400	2.03
	Pomacentrus jenkinsi	11 - 4	.662	.96
White tail	Chromis leucurus	138 - 3	4.397	6.38
Black damsel	Chromis verater	118 - 5	14.308	20.78
Blue damsel	C. ovalis	5 - 3	.113	.16
Hinalea lauwili	Thalassoma duperreyi	26 - 6 5 - 3	2.761	4.01
Birdfish (hinalea i'iwi)	Gomphosus varius	7 - 4	.143	.21
Hinalea lolo	Coris gaimardi	7 - 8	1.577	2.29
Labroides	Labroides phthirophagus	3 - 3	.037	.05
Omaka	Stethojulis axillaris	10 - 4 5 - 6	.895	1.30
Poou	Cheilinus rhodochrous	14 - 5 2 - 14	4.053	5.89
Uhu	Scarus dubius	22 - 6 12 - 10	12.564	18.24
Band snout	S. perspicillatus	1 - 20 2 - 18 1 - 8	15.940	23.15
	S. sordidus	1 - 15	2.531	3.68
Kihikihi	Zanclus canescens	8 - 4	.625	.91

TABLE 31 (continued)

COMMON NAME	SCIENTIFIC NAME	No. fish $\bar{x}$ l. in inches	Weight in Pounds Σ for fish	Per acre
Maiko	Acanthurus nigrofuscus	33 - 4	1.373	1.99
Maiko	A. nigroris	36 - 4	1.567	2.28
Naenae	A. olivaceus	1 - 6	.147	.21
Palani	A. dussumieri	3 - 7 4 - 10	3.671	5.33
Kole	Ctenochaetus strigosus	70 - 4	4.211	6.11
Yellow manini	Zebrasoma flavescens	72 - 4	4.055	5.89
Sailfin tang	Z. veliferum	1 - 5	.110	.16
Kala	Naso lituratus	66 - 7	22.864	33.20
Humuhumu	Balistes bursa	4 - 7	1.221	1.77
Humuhumi-mimi	B. capistratus	1 - 8	.507	.74
Humuhumu-uli	Melichthys vidua	2 - 6	.475	.69
Humuhumu-ele'ele	M. buniva	5 - 4	.352	.51
Oili uwiwi	Pervagor spilosoma	1 - 4	.049	.07

TABLE 32. Fish species, number, length and weight observed on transect 5, 12-II-69, 1006 to 1025 hours. The transect begins at depth 75 feet and ends at depth 23 feet. Accounted for are 45 species and 121.56 pounds of fish per acre.

COMMON NAME	SCIENTIFIC NAME	No. fish $\bar{x}$ l. in inches	Weight in Pounds Σ for fish	Per acre
Puhi paka	Gymnothorax flavimarginatus	2 - 24	2.488	3.61
U'u	Myripristis berndti	2 - 6	.328	.48
Malu	Parupeneus pleurostigma	2 - 6	.194	.28
Moano	P. multifasciatus	12 - 6	1.374	2.00
Mu	Monotaxis grandoculis	4 - 8 1 - 15	3.037	4.41

TABLE 32 (continued)

COMMON NAME	SCIENTIFIC NAME	No. fish $\bar{x}$ l. in inches	Weight in Pounds ∠ for fish	Weight in Pounds Per acre
Potter's angel	Centropyge potteri	17 - 4	1.208	1.75
Longnose butterfly	Forcipiger longirostris	38 - 5	2.233	3.24
Orange striped	Chaetodon ornatissimus	5 - 6	1.253	1.82
	C. multicinctus	26 - 4	1.731	2.51
	C. unimaculatus	1 - 4	.061	.09
	C. lunula	8 - 7	2.991	4.34
Pilikoa	Paracirrhites forsteri	2 - 4	.090	.13
Maomao	Abudefduf abdominalis	1 - 4	.069	.10
	Pomacentrus jenkinsi	7 - 4	.421	.61
Aloiloi	Dascyllus albisella	3 - 4	.225	.33
White tail	Chromis leucurus	55 - 3	1.752	2.54
Black damsel	C. verater	8 - 6	1.676	2.43
Blue damsel	C. ovalis	1 - 4	.054	.08
Hinalea lauwili	Thalassoma duperreyi	28 - 5	1.680	2.44
Birdfish (hinalea i'iwi)	Gomphosus varius	7 - 5	.280	.41
Hinalea lolo	Coris gaimardi	13 - 6	1.236	1.80
Hilu	C. flavovittata	1 - 5	.054	.08
Labroides	Labroides phthirophagus	5 - 3	.061	.09
	Novaculichthys taeniourus	1 - 6	.162	.24
Omaka	Stethojulis axillaris	1 - 5	.065	.09
Poou	Cheilinus rhodochrous	2 - 13	2.461	3.57
Uhu	Scarus dubius	27 - 7	6.946	10.09
Band snout	S. perspicillatus	2 - 14	4.336	6.30
	S. sordidus	15 - 7 17 - 10	16.609	24.12
Sleeping uhu	Calotomus sandvicensis	6 - 6	1.050	1.53

TABLE 32 (continued)

COMMON NAME	SCIENTIFIC NAME	No. fish $\bar{x}$ l. in inches	Weight in Pounds Σ for fish	Per acre
Kihikihi	Zanclus canescens	22 - 5	3.355	4.87
White-banded maiko	Acanthurus leucopareius	8 - 6	1.348	1.96
Maiko	A. nigroris	3 - 4	.131	.19
Naenae	A. olivaceus	3 - 8	1.045	1.52
Manini	A. sandvicensis	2 - 6	.363	.53
Pualu	A. xanthopterus	1 - 6	.173	.25
	A. mata	11 - 4	.528	.77
Kole	Ctenochaetus strigosus	78 - 5	9.165	13.31
Yellow manini	Zebrasoma flavescens	111 - 4	6.252	9.08
Kala	Naso hexacanthus	7 - 7	1.297	1.88
Kala	N. lituratus	1 - 7	.346	.50
Humuhumu	Balistes bursa	8 - 7	2.442	3.55
Humuhumu-uli	Melichthys vidua	1 - 5	.138	.20
	Xanthichthys ringens	1 - 8	.512	.74
Nenue	Kyphosus cinerescens	3 - 6	.480	.70

TABLE 33. Fish species, number, length and weight observed on transect 6, 5-VI-68, 1112 to 1137 hours. The transect begins at depth 30 feet and ends at depth 25 feet. Accounted for are 48 species and 275.55 pounds of fish per acre.

COMMON NAME	SCIENTIFIC NAME	No. fish $\bar{x}$ l. in inches	Weight in Pounds Σ for fish	Per acre
U'u	Myripristis berndti	34 - 5 10 - 4	3.716	5.40
Red weke	Mulloidichthys auriflamma	1 - 6	.095	.14
Manu	Parupeneus bifasciatus	1 - 6	.108	.16
Moano	P. multifasciatus	3-8 , 1-6 , 3-5 2-4	1.194	1.73
Moana kea	P. chryserydros	1 - 7	.182	.26
Mu	Monotaxis grandoculis	2 - 8	.573	.83
Potter's angel	Centropyge potteri	7 - 4 , 3 - 5	.913	1.33
Longnose butterfly	Forcipiger longirostris	2-5 , 22-4	.780	1.13
Blue stripe	Chaetodon fremblii	3 - 4	.182	.26
Orange striped	C. ornatissimus	3-3 , 20-5 , 21-4	4.553	6.61
	C. lunula	2 - 5	.273	.40
	C. quadrimaculatus	3 - 5	.356	.52
	C. multicinctus	11 - 4 , 5 - 6	1.855	2.69
Maomao	Abudefduf abdominalis	25 - 5	3.375	4.90
Yellow eye damsel	Pomacentrus jenkinsi	7 - 3 , 10 - 5	1.353	1.96
Aloiloi	Dascyllus albisella	1 - 3 , 5 - 4	.406	.59
White tail	Chromis leucurus	67 - 3	2.135	3.10
Blue damsel	Chromis ovalis	7-4 , 5-3 , 1-5	.594	.86
Hinalea lauwili	Thalassoma duperreyi	23-5 , 24-4 14-6 , 10-7	5.215	7.57
Hinalea luahine	T. ballieui	4 - 6	.518	.75

TABLE 33 (continued)

COMMON NAME	SCIENTIFIC NAME	No. fish $\bar{x}$ l. in inches	Weight in Pounds Σ for fish	Per acre
Birdfish	Gomphosus varius	1 - 4	.020	.03
Opule	Anampses cuvieri	2 - 5	.150	.22
Labroides	Labroides phthirophagus	1 - 3	.012	.02
	Novaculichthys taeniourus	1 - 5	.094	.14
Omaka	Stethojulis axillaris	2 - 3	.028	.04
Poou	Cheilinus rhodochrous	1 - 6	.121	.18
	Pseudocheilinus octotaenia	1 - 4	.035	.05
Uhu	Scarus dubius	2 - 3	.041	.06
Band snout	S. perspicillatus	1 - 18	4.607	6.69
Kihikihi	Zanclus canescens	12 - 5	1.830	2.66
Pakuikui	Acanthurus achilles	4-3 , 1 - 6	.279	.41
White-banded maiko	A. leucopareius	8 - 6	1.348	1.96
Maiko	A. nigroris	13 - 4	.566	.82
Naenae	A. olivaceus	3-6 , 3-4 , 6 - 5	1.082	1.57
Manini	A. sandvicensis	3 - 3	.068	.10
Palani	A. dussumieri	4 - 6	.631	.92
Pualu	A. xanthopterus	1 - 8 , 6 - 6	1.447	2.10
Kole	Ctenochaetus strigosus	142 - 4 25 - 3	9.178	13.33
Yellow manini	Zebrasoma flavescens	189 - 4	10.644	15.46
Kala	Naso unicornis	16 - 18 , 6 - 12 1 - 6	66.494	96.55
Kala	N. lituratus	25-12 , 36-4 , 23-8	57.853	84.00
Black kole	Ctenochaetus hawaiiensis	1 - 6	.203	.29
Sailfin tang	Zebrasoma veliferum	3 - 8	1.352	1.96

TABLE 33 (continued)

COMMON NAME	SCIENTIFIC NAME	No. fish $\bar{x}$ l. in inches	Weight in Pounds Σ for fish	Per acre
Humuhumu	Balistes bursa	5 - 5	.556	.81
Humuhumu-ele'ele	Melichthys buniva	3 - 6 , 3 - 4	.924	1.34
Oili uwiwi	Pervagor spilosoma	5 - 4	.243	.35
Moa	Ostracion lentiginosus	2 - 2	--	--
Keke	Arothron hispidus	1 - 12	1.585	2.30

TABLE 34. Fish species, number, length and weight observed on transect 6, 14-VIII-68, 0950 to 1023 hours. The transect begins at depth 20 feet and ends at depth 18 feet. Accounted for are 57 species and 273.93 pounds of fish per acre.

COMMON NAME	SCIENTIFIC NAME	No. fish $\bar{x}$ l. in inches	Weight in Pounds Σ for fish	Per acre
Trumpet fish	Aulostomus chinensis	3 - 8 1 - 12	.196	.29
Alaihi	Holocentrus xantherythrus	1 - 4	.039	.06
U'u	Myripristis berndti	17 - 6	2.791	4.05
Kahala	Seriola dumerilii	1 - 12	1.037	1.51
Red weke	Mulloidichthys auriflamma	15 - 5	.825	1.20
Malu	Parupeneus pleurostigma	1 - 5	.056	.08
Moano	P. multifasciatus 10 - 7"	2 - 12	3.650	5.30
Moana-kea	P. chryserydros	4 - 6	.458	.67
Mu	Monotaxis grandoculis	1 - 6	.121	.18
Potter's angel	Centropyge potteri	6 - 3	.180	.26
Longnose butterfly	Forcipiger longirostris	35 - 5'	2.056	2.99
Blue stripe	Chaetodon fremblii	3 - 5	.356	.52
Orange striped	C. ornatissimus 4 - 8"	5 - 5	3.101	4.50

COMMON NAME	SCIENTIFIC NAME	No. fish x̄ l. in inches	Weight in Pounds Σ for fish	Per acre
	C. lunula	1 - 6	.235	.34
	C. quadrimaculatus	10 - 5	1.188	1.73
	C. multincinctus	27 - 4	1.797	2.61
	Hemitaurichthys zoster	1 - 4	.065	.09
Pilikoa	Paracirrhites cinctus	1 - 6	.160	.23
Pilikoa	P. forsteri	2 - 5	.175	.25
Pilikoa	P. arcatus	4 - 6	.631	.92
Poo-paa	Cirrhitus alternatus	1 - 6	.173	.25
	Pomacentrus jenkinsi	41 - 5	4.818	7.00
Aloiloi	Dascyllus albisella	30 - 5	4.388	6.37
White tail	Chromis leucurus	65 - 3	2.071	3.01
Black damsel	C. verater	133 - 5	16.126	23.42
Blue damsel	C. ovalis	54 - 5	5.670	8.23
Hinalea lauwili	Thalassoma duperreyi	89 - 5	5.340	7.75
Birdfish (hinalea i'iwi)	Gomphosus varius	7 - 4 2 - 8	.471	.68
Labroides	Labroides phthirophagus	8 - 3	.097	.14
Ohua	Stethojulis albovittata	6 - 5	.405	.59
Uhu	Scarus dubius	17 - 6	2.754	4.00
Band snout	S. perspicillatus	1 - 24	10.921	15.86
Limu teeth	Scarops jordani	1 - 12	1.296	1.88
Sleeping uhu	Calotomus sandvicensis	1 - 6	.175	.25
Kihikihi	Zanclus canescens	14 - 4	1.093	1.59
Surf maiko	Acanthurus guttatus	21 - 6	7.830	11.37
Pakuikui	A. achilles	1 - 12 6 - 5	.645	.94

COMMON NAME	SCIENTIFIC NAME	No. fish $\bar{x}$ l. in inches	Weight in Pounds	
			Σ for fish	Per acre
White-banded maiko	A. leucopareius	32 - 7	8.561	12.43
Maiko	A. nigrofuscus	1 - 6	.140	.20
Maiko	A. nigroris	7 - 4	.305	.44
Naenae	Acanthurus olivaceus	3 - 7	.700	1.02
Manini	A. sandvicensis	9 - 5	.945	1.37
Palani	A. dussumieri	1 - 12	1.261	1.83
Pualu	A. mata	31 - 5	2.906	4.22
Kole	Ctenochaetus strigosus	154 - 4	9.265	13.45
Hawaiian kole	C. hawaiianensis	1 - 5	.118	.17
Yellow manini	Zebrasoma flavescens	186 - 6	35.355	51.34
Kala	Naso hexacanthus	3 - 5	.203	.30
Kala	N. unicornis	1 - 15	2.160	3.14
Kala	N. lituratus	5 - 10	9.721	14.12
Humuhumu	Balistes bursa	37 - 5 3 - 6	.577	.84
Humuhumi-mimi	B. capistratus	1 - 6	.214	.31
Humuhumu-uli	Melichthys vidua	1 - 12	1.901	2.76
Humuhumu-ele'ele	M. buniva	17 - 5	2.338	3.40
Oili uwiwi	Pervagor spilosoma	5 - 4 2 - 6	.571	.83
Moa	Ostracion lentiginosus	7 - 3	--	--
Awa	Chanos chanos	1 - 6	27.994	40.65

TABLE 35. Fish species, number, length and weight observed on transect 6, 30-X-68, 1625 to 1650 hours. The transect begins at depth 20 feet and ends at depth 18 feet. Accounted for are 69 species and 603.07 pounds of fish per acre.

COMMON NAME	SCIENTIFIC NAME	No. fish $\bar{x}$ l. in inches	Weight in Pounds	
			∠ for fish	Per acre
Lizard fish	Synodous variegatus	1 - 5	.040	.06
Trumpet fish	Aulostomus chinensis	2 - 16	.492	.71
Alaihi	Holocentrus xantherythrus	4 - 5	.305	.44
U'u	Myripristis berndti	30 - 5	3.325	4.83
	M. multiradiatus	1 - 5	.110	.16
Introduced Roi	Cephalopholis argus	1 - 10	.500	.73
Upapalu	Apogon snyderi	1 - 4	.040	.06
Omilu	Caranx melampygus	5 - 10	3.200	4.65
Uku	Aprion virescens	1 - 10	.600	.87
Gurutsu	Aphareus furcatus	1 - 10	.600	.87
Spot weke	Mulloidichthys samoensis	1 - 7	.165	.24
Red weke	M. auriflamma	9 - 6	.855	1.24
Manu	Parupeneus bifasciatus	12 - 8	3.072	4.46
Moano	P. multifasciatus	33 - 7	5.999	8.71
Moana kea	P. chryserydros	1 - 6	.115	.17
Mu	Monotaxis grandoculis	4 - 7 6 - 12	6.574	9.55
Potter's angel	Centropyge potteri	30 - 4	2.131	3.09
Longnose butterfly	Forcipiger longirostris	83 - 5	4.876	7.08
Blue stripe	Chaetodon fremblii	33 - 4	2.006	2.91
Orange striped	C. ornatissimus	19 - 6	4.761	6.91
	C. lunula	7 - 6	1.648	2.39

TABLE 35 (continued)

COMMON NAME	SCIENTIFIC NAME	No. fish $\bar{x}$ l. in inches	Weight in Pounds Σ for fish	Per acre
	C. multicinctus	70 - 4	4.659	6.77
	C. quadrimaculatus	22 - 4	1.338	1.94
Pilikoa	Paracirrhites cinctus	4 - 6	.639	.93
Pilikoa	P. forsteri	2 - 6	.302	.44
Pilikoa	P. arcatus	6 - 3	.118	.17
Maomao	Abudefduf abdominalis	16 - 4	1.106	1.61
Kupipi	A. sordidus	1 - 5	.079	.12
	Pomacentrus jenkinsi	66 - 4	3.971	5.77
Aloiloi	Dascyllus albisella	117 - 4	8.761	12.72
	Chromis dimidiatus	1 - 2	.009	.01
White tail	C. leucurus	100 - 4	7.552	10.97
Black damsel	C. verater	21 - 6	4.400	6.39
Blue damsel	C. ovalis	1 - 4	.054	.08
Hinalea lauwili	Thalassoma duperreyi	63 - 5	3.780	5.49
Hinalea lauhine	T. ballieui	8 - 8	2.458	3.57
Birdfish (hinalea i'iwi)	Gomphosus varius	19 - 5	.760	1.10
Hinalea lolo	Coris gaimardi	4 - 7	.604	.88
Opule	Anampses cuvieri	2 - 6	.259	.38
	A. rubrocaudatus	1 - 3	.012	.02
Labroides	Labroides phthirophagus	1 - 4	.029	.04
Poou	Cheilinus rhodochrous	1 - 8	.287	.42
Uhu	Scarus dubius	1 - 14 13 - 8	7.050	10.24
Band snout	S. perspicillatus	2 - 18	9.215	13.38

COMMON NAME	SCIENTIFIC NAME	No. fish $\bar{x}$ l. in inches	Weight in Pounds Σ for fish	Per acre
	S. sordidus	7 - 8	2.688	3.90
Kihikihi	Zanclus canescens	127 - 5	19.368	28.12
Surf maiko	Acanthurus guttatus	73 - 7	31.299	45.45
Pakuikui	A. achilles	8 - 6	1.486	2.16
White-banded maiko	A. leucopareius	40 - 8	15.974	23.19
Maiko	A. nigrofuscus	62 - 4	2.579	3.75
Maiko	A. nigroris	98 - 4	4.265	6.19
Naenae	A. olivaceus	2 - 8	.696	1.01
Manini	A. sandvicensis	29 - 5	3.045	4.42
Palani	A. dussumieri	12 - 10	8.760	12.72
Pualu	A. xanthopterus	15 - 6	2.592	3.76
Pualu	A. mata	8 - 6	1.296	1.88
Kole	Ctenochaetus strigosus	372 - 5	43.710	63.47
Yellow manini	Zebrasoma flavescens	246 - 5	27.060	39.29
Sailfin tang	Z. veliferum	1 - 7 1 - 4	.358	.52
Kala	Naso hexacanthus	100 - 6	11.664	16.94
Kala	Naso unicornis	25 - 19	109.744	159.35
Kala	N. lituratus	19 - 7	6.582	9.56
Humuhumu	Balistes bursa	12 - 6	2.307	3.35
Humuhumi-mimi	B. capistratus	1 - 6	.214	.31
Humuhumu-ele'ele	Melichthys buniva	5 - 5	.688	1.00
Oili uwiwi	Pervagor spilosoma	4 - 3	.082	.12
Moa	Ostracion lentiginosus	11 - 3	---	---

TABLE 35 (continued)

COMMON NAME	SCIENTIFIC NAME	No. fish x̄ l. in inches	Weight in Pounds ≤ for fish	Per acre
Blenny	Cirripectus obscurus	1 - 4	---	---
	Iso hawaiiensis	2,000,000 - 1	20.00	29.04

TABLE 36. Fish species, number, length and weight observed on transect 6, 13-II-69, 1117 to 1140 hours. The transect begins at depth 25 feet and ends at depth 20 feet. Accounted for are 54 species and 599.41 pounds of fish per acre.

COMMON NAME	SCIENTIFIC NAME	No. fish x̄ l. in inches	Weight in Pounds ≤ for fish	Per acre
Trumpet fish	Aulostomus chinensis	1 - 18	.350	.51
	Holocentrus scythrops	1 - 7	.213	.31
U'u	Myripristis berndti	7 - 6	1.149	1.67
Gurutsu	Aphareus furcatus	1 - 8	.307	.45
Red weke	Mulloidichthys auriflamma	1 - 6	.095	.14
Malu	Parupeneus pleurostigma	2 - 6	.194	.28
Moano	P. multifasciatus	42 - 8	13.025	18.91
Mu	Monotaxis grandoculis	2 - 10	1.120	1.63
Potter's angel	Centropyge potteri	27 - 4	1.918	2.79
Longnose butterfly	Forcipiger longirostris	65 - 5	3.819	5.55
Blue stripe	Chaetodon fremblii	7 - 4	.426	.62
Orange striped	C. ornatissimus	43 - 7	17.109	24.84
	C. multicinctus	79 - 4	5.258	7.64
	C. unimaculatus	6 - 4	.365	.53
	C. lunula	16 - 6	3.767	5.47
	C. quadrimaculatus	16 - 5	1.900	2176

TABLE 36 (continued)

COMMON NAME	SCIENTIFIC NAME	No. fish $\bar{x}$ l. in inches	Weight in Pounds Σ for fish	Weight in Pounds Per acre
Pilikoa	Paracirrhites cinctus	1 - 4	.047	.07
	P. forsteri	1 - 7	.240	.35
	P. arcatus	3 - 3	.059	.09
Maomao	Abudefduf abdominalis	7 - 4	.484	.70
	A. imparipennis	52 - 2	.262	.38
	Pomacentrus jenkinsi	17 - 4	1.023	1.49
Aloiloi	Dascyllus albisella	32 - 5	4.680	6.80
White tail	Chromis leucurus	20 - 3	.669	.97
Blue damsel	C. ovalis	21 - 3	.476	.69
Hinalea lauwili	Thalassoma duperreyi	66 - 5	3.960	5.75
Birdfish (hinalea i'iwi)	Gomphosus varius	18 - 5	.720	1.05
Hinalea lòlo	Coris gaimardi	18 - 5	.990	1.44
Labroides	Labroides phthirophagus	7 - 3	.085	.12
	Novaculichthys taeniourus	1 - 4	.048	.07
Uhu	Scarus dubius	33 - 7	8.489	12.33
Band snout	S. perspicillatus	2 - 14 1 - 18	8.943	12.99
	S. sordidus	18 - 8	27.648	40.15
Kihikihi	Zanclus canescens	56 - 5	8.540	12.40
Surf maiko	Acanthurus guttatus	67 - 8	42.880	62.26
Pakuikui	A. achilles	29 - 8	12.769	18.54
White-banded maiko	A. leucopareius	76 - 10	59.280	86.08
Maiko	A. nigrofuscus	70 - 5	5.688	8.26
	A. nigroris	125 - 5	10.625	15.43

TABLE 36 (continued)

COMMON NAME	SCIENTIFIC NAME	No. fish $\bar{x}$ 1. in inches	Weight in Pounds ∑ for fish	Per acre
Naenae	Acanthurus olivaceus	10 - 7	2.332	3.39
Manini	A. sandvicensis	3 - 5	.315	.46
Palani	A. dussumieri	5 - 10	3.650	5.30
Pualu	A. mata	21 - 5	1.969	2.86
Kole	Ctenochaetus strigosus	215 - 5	25.263	36.68
Yellow manini	Zebrasoma flavescens	230 - 5	25.300	36.74
Sailfin tang	Z. veliferum	2 - 8	.901	1.31
Kala	Naso hexacanthus	42 - 7	7.779	11.30
	N. unicornis	34 - 13	47.807	69.42
	N. lituratus	95 - 6 20 - 10	40.925	59.42
Humuhumu	Balistes bursa	16 - 6	3.076	4.47
Humuhumu-ele'ele	Melichthys buniva	5 - 8	2.816	4.09
	Xanthichthys ringens	2 - 5	.250	.36
Moa	Ostracion lentiginosus	2 - 3	--*	--*
Nenue	Kyphosus cinerescens	2 - 8	.758	1.10

TABLE 37. Fish species, number, length and weight observed on transect 7, 5-VI-68, 0940 to 1017 hours. The transect begins at depth 80 feet and ends at depth 20 feet. Accounted for are 47 species and 323.60 pounds of fish per acre.

COMMON NAME	SCIENTIFIC NAME	No. fish x̄ l. in inches	Weight in Pounds ∠ for fish	Weight in Pounds Per acre
U'u	Myripristis berndti	36 - 4 28 - 6	6.347	9.22
	Priacanthus cruentatus	3 - 7	.576	.84
Upapalu	Apogon snyderi	3 - 6	.408	.59
Spot weke	Mulloidichthys samoensis	8 - 4 1 - 6	.350	.51
Red weke	M. auriflamma	50 - 8	11.264	16.36
Kumu	Parupeneus porphyreus	4 - 8 20 - 4	1.897	2.75
Moano	P. multifasciatus	18 - 6 10 - 5	2.724	3.96
	Monotaxis grandoculis	1 - 8	.287	.42
Black-white angel	Holacanthus arcuatus	4 - 4	.284	.41
Potter's angel	Centropyge potteri	6-4 , 27 - 3	1.235	1.79
Longnose butterfly	Forcipiger longirostris	60-4 , 10-5	2.393	3.47
Orange striped	Chaetodon ornatissimus	202 - 5	29.290	42.53
	C. multicinctus	64 - 4	4.260	6.19
Pilikoa	Paracirrhites forsteri	3 - 4	.134	.20
Yellow eye damsel	Pomacentrus jenkinsi	33 - 3	.838	1.22
Aloiloi	Dascyllus albisella	426 - 4	31.899	46.32
White tail	Chromis leucurus	36 - 3	1.147	1.67
Black damsel	C. verater	5 - 4 , 23 - 5	3.099	4.50

TABLE 37 (continued)

COMMON NAME	SCIENTIFIC NAME	No. fish x̄ 1. in inches	Weight in Pounds ℓ for fish	Per acre
Blue damsel	C. ovalis	186 - 3 , 3 - 4	4.379	6.36
Hinalea lauwili	Thalassoma duperreyi	70 - 5 , 13 - 6	5.548	8.06
Hinalea luahine	T. ballieui	9 - 6	1.166	1.69
Birdfish (hinalea i'iwi)	Gomphosus varius	4 - 4	.082	.12
Hilu	Coris flavovittata	2 - 6	.186	.27
Opule	Anampses cuvieri	5 - 5	.375	.55
Labroides	Labroides phthirophagus	1 - 3	.012	.02
Poou	Cheilinus rhodochrous	13 - 6	1.572	2.28
	Pseudocheilinus octotaenia	1 - 4	.035	.05
Uhu	Scarus dubius	22 - 8	8.448	12.27
Band snout	S. perspicillatus	1-18 , 1 - 9	5.183	7.53
	S. sordidus	5 - 8	1.920	2.79
Kihikihi	Zanclus canescens	10 - 4	.781	.93
Pakuikui	Acanthurus achilles	3-4 , 5 - 3	.281	.41
White-banded maiko	A. leucopareius	2 - 6	.337	.49
Maiko	A. nigroris	16 - 4	.696	1.01
Naenae	A. olivaceus	5 - 8 , 1 - 12	2.916	4.23
Manini	A. sandvicensis	16 - 5	1.680	2.44
Palani	A. dussumieri	110 - 5 , 2 - 18	18.553	26.94
Pualu	A. xanthopterus	3 - 4	.154	.22
Kole	Ctenochaetus strigosus	269 - 4	16.183	23.50
Yellow manini	Zebrasoma flavescens	258 - 4 6 - 9	18.380	26.69
Kala	Naso hexacanthus	3 - 4 , 4 - 10 100 - 6	13.928	20.22

TABLE 37 (continued)

COMMON NAME	SCIENTIFIC NAME	No. fish $\bar{x}$ l. in inches	Weight in Pounds Σ for fish	Per acre
Kala	Naso lituratus	4 - 10	4.04	5.87
Humuhumu	Balistes bursa	5-8 , 13-4 , 4-6	3.787	5.50
Humuhumu-uli	Melichthys vidua	5 - 4 , 6 - 5	1.177	1.71
Humuhumu-ele'ele	M. buniva	34 - 6 , 63 - 4	12.513	18.17
Sharp nose puffer	Canthigaster rivulatus	1 - .6	.229	.33
Blenny	BLENNIDAE	1 - 6	--	--

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TABLE 38. Fish species, number, length and weight observed on transect 7, 12-VIII-68, 1700 to 1725 hours. The transect begins at depth 60 feet and ends at depth 20 feet. Accounted for are 49 species and 138.03 pounds of fish per acre.

COMMON NAME	SCIENTIFIC NAME	No. fish $\bar{x}$ l. in inches	Weight in Pounds Σ for fish	Per acre
	Synodous variegatus	1 - 12	.553	.80
Puhi paka	Gymnothorax flavimarginatus	1 - 24	1.244	1.81
Trumpet fish	Aulostomus chinensis 1-6",	3-12 2-24	1.983	2.88
Alaihi mama	Holotrachys lima	1 - 12	1.901	2.76
U'u	Myripristis berndti	86 - 6	14.118	20.50
Upapalu	Apogon snyderi	2 - 6	.272	.40
Spot weke	Mulloidichthys samoensis	30 - 6	3.110	4.52
Malu	Parupeneus pleurostigma	1 - 6	.097	.14
Kumu	P. porphyreus	1 - 6	.123	.18
Manu	P. bifasciatus	1 - 6	.108	.16
Moano	P. multifasciatus 1-8"	4 - 6	.729	1.06
Potter's angel	Centropyge potteri	17 - 3	.510	.74
Longnose butterfly	Forcipiger longirostris	40 - 4	1.203	1.75

TABLE 38 (continued)

COMMON NAME	SCIENTIFIC NAME	No. fish x̄ l. in inches	Weight in Pounds ≤ for fish	Per acre
Orange striped	Chaetodon ornatissimus	18 - 5	2.610	3.79
	C. lunula	1 - 4	.070	.10
	C. multicinctus	23 - 4	1.531	2.22
Pilikoa	Paracirrhites arcatus	1 - 4	.047	.07
	Pomacentrus jenkinsi	11 - 4	.662	.96
Aloiloi	Dascyllus albisella	66 - 4	4.942	7.18
White tail	Chromis leucurus	15 - 3	.478	.69
Black damsel	C. verater	150 - 5	18.188	26.41
Blue damsel	C. ovalis	25 - 3	.567	.82
Hinalea lauwili	Thalassoma duperreyi	33 - 4	1.014	1.47
Birdfish (hinalea i'iwi)	Gomphosus varius	9 - 4	.184	.27
Hinalea lolo	Coris gaimardi	2 - 6	.190	.28
Opule	Anampses cuvieri	3 - 4	.115	.17
	A. rubrocaudatus	2 - 4	.056	.08
	Novaculichthys taeniourus s	1 - 5	.094	.14
Ohua	Stethojulis albovittata	1 - 5	.068	.10
	S. axillaris	2 - 4	.067	.10
Poou	Cheilinus bimaculatus	5 - 6	.724	1.05
Uhu	Scarus dubius	5 - 8	1.920	2.79
Kihikihi	Zanclus canescens	9 - 4	.703	1.02
Pakuikui	Acanthurus achilles	3 - 5	.323	.47
White-banded maiko	A. leucopareius	3 - 6	.505	.73
Maiko	A. nigrofuscus	10 - 4	.416	.60
Maiko	A. nigroris	5 - 4	.218	.32

TABLE 38 (continued)

COMMON NAME	SCIENTIFIC NAME	No. fish x̄ l. in inches	Weight in Pounds ≰ for fish	Per acre
Palani	A. dussumieri	3 - 6	.473	.69
Kole	Ctenochaetus strigosus	107 - 4	6.437	9.35
Hawaiian kole	C. hawaiianensis	3 - 4	.181	.26
Yellow manini	Zebrasoma flavescens	191 - 4	10.757	15.62
Kala	Naso hexacanthus	15 - 6	1.750	2.54
Kala	N. lituratus	6 - 6	1.309	1.90
Humuhumu	Balistes bursa	7 - 6	1.346	1.95
Humuhumu-ele'ele	Melichthys buniva 13-8"	26 - 5	10.897	15.82
	Xanthichthys ringens	1 - 5	.125	.18
Oili uwiwi	Pervagor spilosoma	4 - 3	.082	.12
Moa	Ostraction lentiginosus	1 - 3 1 - 5	--	--
Spotted puffer	Canthigaster jactator	2 - 3	.051	.07

TABLE 39. Fish species, number, length and weight observed on transect 7, 31-X-68, 1023 to 1045 hours. The transect begins at depth 65 feet and ends at depth 20 feet. Accounted for are 49 species and 306.16 pounds of fish per acre.

COMMON NAME	SCIENTIFIC NAME	No. fish x̄ l. in inches	Weight in Pounds ≰ for fish	Per acre
Cornet Fish	Fistularia petimba	1 - 12	.035	.05
Trumpet fish	Aulostomus chinensis	7 - 20	3.360	4.88
Alaihi	Holocentrus xantherythrus	1 - 4	.039	.06
	Holotrachys lima	1 - 14	3.018	4.38
U'u	Myripristis berndti	55 - 6	9.029	13.11
Upapalu	Apogon snyderi	1 - 4	.040	.06
Spot weke	Mulloidichthys samoensis	475 - 6	49.248	71.51

COMMON NAME	SCIENTIFIC NAME	No. fish $\bar{x}$ l. in inches	Weight in Pounds	
			Σ for fish	Per acre
Red weke	M. auriflamma	10 - 6	.950	1.38
Kumu	Parupeneus porphyreus	2 - 12	1.970	2.86
Manu	P. bifasciatus	8 - 6	.864	1.26
Moano	P. multifasciatus	12 - 6	1.374	2.00
Mu	Monotaxis grandoculis	4 - 6	.484	.70
Potter's angel	Centropyge potteri	70 - 4	4.973	7.22
Longnose butterfly	Forcipiger longirostris	59 - 4	1.77	2.58
Blue stripe	Chaetodon fremblii	7 - 4	.426	.62
Orange striped	C. ornatissimus	38 - 5	5.510	8.00
Puka	Chaetodon miliaris	1 - 6	.203	.29
	C. trifasciatus	1 - 4	.065	.09
	C. lunula	4 - 6	.942	1.37
	C. multicinctus	51 - 4	3.395	4.93
Pilikoa	Paracirrhites forsteri	1 - 8	.358	.52
	Pomacentrus jenkinsi	48 - 4	2.888	4.19
Aloiloi	Dascyllus albisella	30 - 4	2.246	3.26
White tail	Chromis leucurus	111 - 3	3.537	5.14
Black damsel	C. verater	275 - 5	33.344	48.42
Blue damsel	C. ovalis	36 - 3	.817	1.19
Hinalea lauwili	Thalassoma duperreyi	121 - 5	7.260	10.54
Birdfish (hinalea i'iwi)	Gomphosus varius	17 - 5	.680	.99
Hinalea lolo	Coris gaimardi	33 - 6	3.136	4.55
	Anampses rubrocaudatus	1 - 6	.095	.14
Labroides	Labroides phthirophagus	8 - 3	.097	.14

TABLE 39 (continued)

COMMON NAME	SCIENTIFIC NAME	No. fish $\bar{x}$ l. in inches	Weight in Pounds	
			Σ for fish	Per acre
Poou	Cheilinus rhodochrous	1 - 10	.560	.81
Uhu	Scarus dubius	6 - 8 1 - 12	3.669	5.33
Band snout	S. perspicillatus	1 - 18 1 - 12	5.972	8.67
Sleeping uhu	Calotomus sandvicensis	2 - 8	.829	1.20
Kihikihi	Zanclus canescens	72 - 4	5.622	8.16
Maiko	Acanthurus nigrofuscus	14 - 5	1.138	1.65
Maiko	A. nigroris	53 - 5	4.505	6.54
Pualu	A. mata	22 - 5	2.063	3.00
	Acanthurus thompsoni	1 - 6	.015	.02
Kole	Ctenochaetus strigosus	120 - 4	7.219	10.48
Yellow manini	Zebrasoma flavescens	300 - 4	16.896	24.53
Sailfin tang	Z. veliferum	3 - 5	.330	.48
Kala	Naso lituratus	27 - 6	5.890	8.55
Humuhumu	Balistes bursa	16 - 6	3.076	4.47
Humuhumu-ele'ele	Melichthys buniva	31 - 6	7.366	10.70
	Xanthichthys ringens	4 - 6	3.456	5.02
Oili uwiwi	Pervagor spilosoma	4 - 3	.082	.12
Fairy shrimp	Stenopus hispidus	2 - 3	--	--

TABLE 40. Fish species, number, length and weight observed on transect 7, 11-II-69, 0840 to 0915 hours. The transect begins at depth 65 feet and ends at depth 20 feet. Accounted for are 51 species and 388.24 pounds of fish per acre.

COMMON NAME	SCIENTIFIC NAME	No. fish $\bar{x}$ l. in inches	Weight in Pounds £ for fish	Per acre
Trumpet fish	Aulostomus chinensis	5 - 12	.518	.75
Alaihi	Holocentrus xantherythrus	6 - 4	.234	.34
U'u	Myripristis berndti	76 - 6	12.476	18.12
Opelu	Decapterus pinnulatus	300 - 10	50.000	72.60
Spot weke	Mulloidichthys samoensis	250 - 7 7 - 5	41.580	60.37
Red weke	M. auriflamma	12 - 6	1.141	1.66
Kumu	Parupeneus porphyreus	4 - 9	1.662	2.41
Moano	P. multifasciatus	19 - 7	3.454	5.02
Mu	Monotaxis grandoculis	1 - 8	.287	.42
Potter's angel	Centropyge potteri	80 - 4	5.683	8.25
Longnose butterfly	Forcipiger longirostris	52 - 4	1.564	2.27
Orange striped	Chaetodon ornatissimus	24 - 6	6.013	8.73
	C. multicinctus	61 - 4	4.060	5.90
	C. lunula	11 - 6	2.590	1.76
	C. quadrimaculatus	1 - 4	.061	.09
Pilikoa	Paracirrhites forsteri	1 - 7	.240	.35
	P. arcatus	2 - 5	.183	.27
	Cirrhitoides bimacula	1 - 3	.014	.02
	Pomacentrus jenkinsi	72 - 4	4.332	6.29
Aloiloi	Dascyllus albisella	26 - 5	3.803	5.52
White tail	Chromis leucurus	65 - 3	2.071	3.01

TABLE 40 (continued)

COMMON NAME	SCIENTIFIC NAME	No. fish $\bar{x}$ l. in inches	Weight in Pounds ∠ for fish	Per acre
Black damsel	C. verater	75 - 5	9.094	13.21
Blue damsel	C. ovalis	72 - 5	7.560	10.98
Hinalea lauwili	Thalassoma duperreyi	60 - 5	3.600	5.23
Hinalea lauhine	T. ballieui	1 - 7	.206	.30
Birdfish (hinalea i'iwi)	Gomphosus varius	5 - 5 1 - 2	.202	.29
Hinalea lolo	Coris gaimardi	9 - 5	.495	.72
Labroides	Labroides phthirophagus	5 - 2	.018	.03
	Novaculichthys taeniourus	2 - 6	.324	.47
Poou	Cheilinus rhodochrous	3 - 8	.860	1.25
Uhu	Scarus dubius	7 - 8 3 - 15	10.282	14.93
Band snout	S. perspicillatus	2 - 12 1 - 15	5.396	7.84
Kihikihi	Zanclus canescens	15 - 4	1.171	1.70
Pakuikui	Acanthurus achilles	4 - 5	.430	.62
White-banded maiko	A. leucopareius	12 - 5	1.170	1.70
Maiko	A. nigrofuscus	10 - 4	.416	.60
	A. nigroris	10 - 4	.435	.63
Naenae	Acanthurus olivaceus	1 - 8	.348	.51
Palani	A. dussumieri	2 - 10	1.460	2.12
Pualu	A. xanthopterus	3 - 5	.300	.44
Kole	Ctenochaetus strigosus	179 - 4	10.769	15.64
Yellow manini	Zebrasoma flavescens	151 - 5	16.610	24.12
Sailfin tang	Z. veliferum	1 - 5	.110	.16

COMMON NAME	SCIENTIFIC NAME	No. fish $\bar{x}$ l. in inches	Weight in Pounds	
			Σ for fish	Per acre
Kala	Naso hexacanthus	23 - 5	1.553	2.26
	N. unicornis	10 - 14	17.562	25.50
	N. lituratus	10 - 8 18 - 5	7.444	10.81
Humuhumu	Balistes bursa	19 - 6	3.653	5.30
	Xanthichthys ringens	15 - 5	1.875	2.72
Oili uwiwi	Pervagor spilosoma	13 - 4	.632	.92
Nohu	Scorpaenopsis cacopsis	1 - 28	20.854	30.28
	S. gibbosa	1 - 8	.558	.81

Chapter 13

OTHER MARINE VERTEBRATES

A. Sharks.

In October, 1968, a shark line was stretched overnight across the mouth of Kealakekua Bay. The catch consisted of six sharks, and the population was estimated as moderate. Caught were two *Caracharhinus milberti*, one *C. galapagensis*, one *C. limbatus* and two *Galeocerdo cuvieri*.

Honaunau Bay is much smaller and only unusually are sharks found within its waters. They more often frequent the exposed bays to the south, Alahaka and Ki'ilae, and during the present survey were also sporadically observed offshore between Honaunau Bay and Alahaka Bay.

Residents tell of times when Honaunau Bay was used as a dumping gound for fish market refuse. The dumping occurred each evening at Kapuwa'i cove, and both sharks and ulua (*Caranx* spp.) arrived as if on signal, swimming to the head of the bay up the northern trench.

B. Porpoises.

There is a resident school of spinner porpoises (*Stenella* sp.) in nearby, much larger Kealakekua Bay. From 30 to 80 members are variously estimated, and the animals are quite tame. Passing consideration has been given to training the school in the wild as a tourist display and for use in scientific research.

From June to November, 1968, the school was invariably present in Kealakekua Bay but during the following February and March, were often absent. Fishermen claim the animals roam a wide section of Hawaii's Kona Coast, but raise their young always in Kealakekua Bay.

On February 28, 1969, fifteen porpoises were observed in Honaunau Bay, apparently playing and chasing opelu schools. The animals remained several hours in the vicinity, and swam to the very head of the bay along the north-shore trench. Residents state they are part of the Kaelakekua school, and that members commonly visit Honaunau Bay in the early morning hours.

C. Turtles.

During the present survey, divers reported turtles approximately every third day, singly and in pairs. During the afternoons the turtles may frequently be seen eating seaweed (in particular *Ulva fasciata*) on the shallow reef flat. Residents claim that during high seas, groups of ten to 15 turtles are often present.

D. Whales.

A small school of pilot whales was observed on March 8, 1969, swimming north 500 m off Honaunau Bay. Fishermen claim they are common in winter with the offshore current southerly and strong, leaving in spring as the current slows and turns northwest.

Chapter 14

VASCULAR PLANTS

The shoreline vegetation (Fig. 33, Table 41) is predominately xerophytic scrub with some trees. In ancient times the area above the park (Bryan, 1957) was largely barren lava with pili grass (*Heteropogon contortus*) common in soil pockets. This grass was widely used for thatching houses. Near shorelines grew shady groves of coconut (*Cocos nucifera*), hala (*Pandanus* spp.) and kou (*Cordia subcordata*). Several native medicinal plants such as noni (*Morinda citrifolia*) persist here today.

The predominant vegetation type bordering Alahaka Bay and the north shore of Honaunau Bay today is a mixed opiuma-ekoa scrub forest. It covers most of the flat land between Napoopoo and Honaunau on older but relatively unweathered lava flows at elevations below 500 feet. The vegetation is dominated by large shrubs or small trees of opiuma (*Pithecellobium dulce*) and ekoa (*Leucaena leucocephala*). Among these grow shrubs of lantana (*Lantana camara*), ilima (*Sida* sp.), Christmas berry (*Schinus terebinthifolius*) and hialoa (*Waltheria indica*). Two vines which occur commonly here are a passion flower (*Passiflora foetida*) and a morning glory (*Ipomoea indica*). The sword fern (*Nephrolepis exaltata*) occurs in more open areas, occasionally covering patches of lava several meters in diameter. Along roadsides, where finer soil particles have accumulated, other species occur which are not common on the coarser rocks. These include red top grass (*Rhynchelytrum repens*) and air plant (*Bryophyllum pinnatum*).

The area includes many lava flows of different types, ages and degrees of weathering. The height and vigor of the vegetation varies from flow to flow. On certain flows the opiuma becomes a tree up to 25 feet high, on other flows it is a shrub not more than 10 feet high. At higher elevations other species including trees appear.

The exotic vegetation of the mauka (mountain) side of the park was removed in 1962-1963. The goal was restoration of the lava landscape in its original barren appearance. Eradication was by means of soil

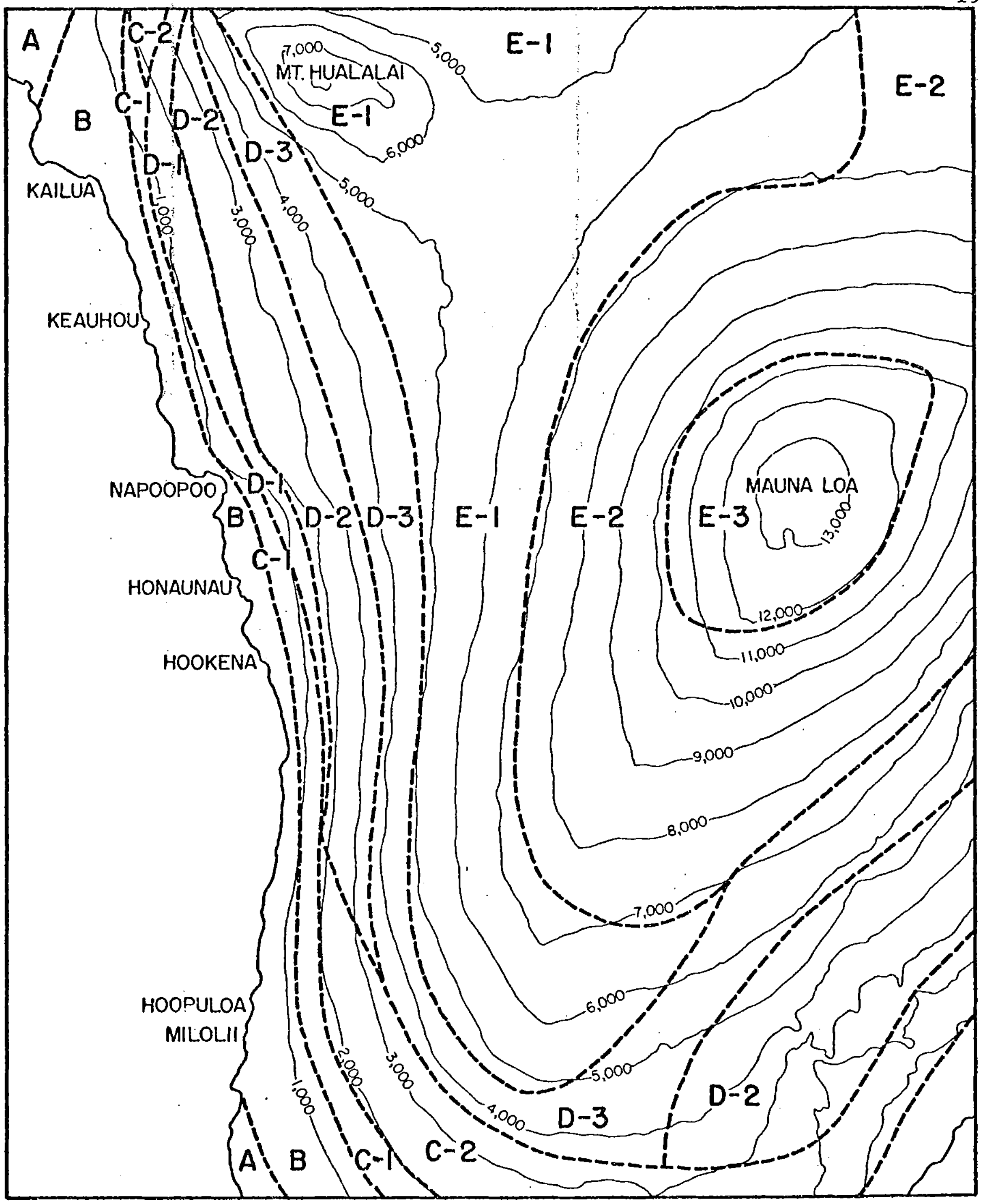

FIGURE 33. Vegetation zones on the Kona slope of Mauna Loa. The zones are described on Table 41. Adapted from Ripperton and Hosaka, 1942.

TABLE 41. Vegetation zones on the Kona slope of Mauna Loa. The distributions of the zones are shown in Figure 33. Adapted from Ripperton and Hosaka, 1942.

Zone	Elevation at Honaunau	Rainfall inches	Natural cover type	Representative species of plants
A	Absent from the Kona slope	20 or less	Xerophytic scrub, coastal fringe	
B	Sea to 500 feet	20 to 40	Xerophytic scrub with some trees	Opiuma, kiawe, coconut, lantana, ekoa, weeds
C-1, low	500 to 1000	40 to 60	Mixed open forest and shrubs	Indigofera, lantana, ekoa, Waltheria, guava
C-2, high	Absent from region			
D-1, low	1000 to 1600	60 to 80	Shrub and closed forest	Ohia lehua, koa, hala, kukui, guava, Boston fern
D-2, med.	1600 to 3400	80 and over	Closed forest	Cibotium and Sadleria ferns, kukui, ohia lehua, koa
D-3, high	3400 to 4800	80 to 50	Open forest	Koa, Dryopteris ferns
E-1, low	4800 to 7000	50 and less	Open forest and scrub	Koa, naio, mamani, pukeawe
E-2, med.	7000 to 10,000	Less than 40 inches	Upland open scrub	Mamani, naio, pukeawe
E-3, high	Above 10,000	Less than 40 inches	No seed-bearing plants; largely base lava	Mosses and lichens; occasional grass, herbs, ferns

sterilant ("Karmex" by Dupont), and subsequent spot blasting was carried out every six months using 2,4,5-T (Monsanto; 34.7 per cent inert ingredients, 65.3 per cent isooctyl ester of 2,4,5-trichlorophen-oxyacetic acid), a hormonal herbicide. The ground was re-sterilized annually until 1965 after which time the program was abandoned. The major soil sterilant used for re-clearing was "Ametryne 80W" (20 per cent inert ingredients, 80 per cent 2-ethylamino-4-isopropylamine-6-methylthio-S-triazine) of Geigy.

At the present time weedy vegetation again dominates. The area is an ekoa (Leucaena leucocephala) thicket with species in abundance typical of the surrounding, uncleared opiuma-ekoa scrub forest. The common plants are hialoa (Waltheria indica), passion flower (Passiflora foetida), morning glory (Ipomoea indica), sword fern (Nephrolepis exaltata), garden spurge (Euphorbia hirta), Madagascar periwinkle (Catharanthus roseus) and klu (Acacia farnesiana). Existing noni (Morinda citrifolia) trees were left unsprayed. The grass present is mostly red top (Rhynchelytrum repens), as introduced forage species.

Mechanical means of weed control were briefly attempted in the City of Refuge clearing project. Sections burned off, however, resprouted from nutrient ashes so vigorously that chemical sprays soon became the sole means of eradication. Previously the Park Service has been (Doty, 1968) cautioned against the use of herbicides. The dangers of residue buildups in the soil and particularly the possibility of runoff into Honaunau Bay where significant ecological changes might occur must be considered.

In the present survey, no quantitative work was done in tracing percolation patterns of spray residues or in determining the length of time these residues remain in the soil. In casually hiking about a hillside area last sprayed over four years ago, weeds were often noted growing competitively in lava pockets next to open soil patches that were totally devoid of plant life.

Some restoration of native plants at the City of Refuge is being undertaken, but the major effort is entirely confined to coconut (Cocos nucifera) trees. The oldest stand within the park was planted in 1904 by Reverend Paris, and these attractive old coconuts presently add much to the Polynesian setting. However, many of the trees are now senescent and their presence is a hazard. These are being replaced on an individual basis by very young specimens. Additional and dense stands of coconuts were planted by the Park Service in 1961-1962 and in 1964.

Restoration of native species other than coconuts has never been extensive. Also, spot blasting with herbicides has resulted in some loss to native species. A group of kou trees (Cordia subcordata) by the Great Wall was decimated by insects after all the nearby weedy vegetation had been removed, leaving the kou exposed.

Some pili grass (Heteropogon contortus) has been reintroduced. In 1962, 16 false kamani trees (Terminalia catappa) were planted but only a few remain today. False kamani, however, is not native. The Park Service had intended to plant the native species, true kamani (Calophyllum inophyllum). Ten fan palms were also planted in 1962 but none survived.

Shoreline trees at the City of Refuge (Table 42, Fig. 34) include coconut (Cocos nucifera), noni (Morinda citrifolia) and one or two specimens of hala (Pandanus sp.) and kou (Cordia subcordata). The sedge Fimbristylis cymosa grows in pockets in the pahoehoe lava close to the sea and another sedge, 'ahu 'awa (Cyperus sp.), grows around the brackish pools near the Great Wall. These plants are native to Hawaii or were introduced by the Polynesians, and were undoubtedly growing here during the period that the City of Refuge was in operation. Also plotted on Figure 34 are the abundant weeds which undergo periodic eradication. The dominant grass is the ubiquitous Bermuda grass (Cynodon dactylon).

By the shoreline opiuma-ekoa thicket at Alahaka Bay is a handsome kou (Cordia subcordata), some false kamani (Terminalia catappa) and several kiawe (Prosopis pallida) and papaya trees (Carica papaya). The dominate grass is again Bermuda grass (Cynodon dactylon). Also present is beach morning glory (Ipomoea pes-caprae) and the exotic shrub, miki palaoa (Cassia occidentalis).

It is estimated that much of the old village of Honaunau was along the northern shore of Honaunau Bay, and within the mixed opiuma-ekoa forest persist scattered remnants of cultivated plants. These include noni (Morinda citrifolia), tamarind (Tamarindus indicus) and breadfruit (Artocarpus altilis). Opiuma is largely replaced here by kiawe.

TABLE 42. Shoreline vegetation at Honaunau Bay. The symbols are those plotted on Figure 34.

Symbol	Scientific name	Symbol	Scientific name
Aa	Alternanthera amoena	Hc	Heteropogon contortus
As	Amaranthus spinosus	Hu	Hylocereus undatus
Ar	Artocarpus altilis	Ii	Ipomoea indica
Bc	Bidens cynapiifolia	Ip	Ipomoea pes-caprae
Bs	Bougainvillea spectabilis	Lc	Lantana camara
Bn	Breynia nivosa	Ll	Leucaena leucocephala
Bp	Bryophyllum pinnatum	Mo	Momordica charantia
Bt	Bryophyllum tubiflorum	Mc	Morinda citrifolia
Cp	Carica papaya	Ne	Nephrolepis exaltata
Cr	Catharanthus roseus	Om	Opuntia magacantha
Ce	Cenchrus echinatus	Pn	Pandanus sp.
Ch	Chenopodium sp.	Pm	Panicum maximum
Cb	Chloris barbata	Pf	Passiflora foetida
Cu	Coccoloba uvifera	Ps	Pennisetum setaceum
Cn	Cocos nucifera	Pd	Pithecelobium dulce
Cm	Commelina benghalensis	Pu	Pluchea odorata
Co	Cordia subcordata	Pa	Plumeria acutifolia
Ct	Cordyline terminalis	Po	Portulaca oleracea
Cs	Cucumis dipsaceus	Pp	Prosopis pallida
Cd	Cynodon dactylon	Rh	Rivina humilis
Cy	Cyperus sp.	Ss	Samanea saman
Ei	Eleusine indica	St	Schinus terebinthifolius
Es	Emilia sonchifolia	Sv	Setaria verticillata
Et	Eragrostis tenella	Ti	Tamarindus indicus
Er	Erythrina sp.	Tp	Tephrosia purpurea
Eh	Euphorbia hirta	Th	Thespesia populnea
Fc	Fimbristylis cymosa	Wi	Waltheria indica
Gg	Gynandropsis gynandra		

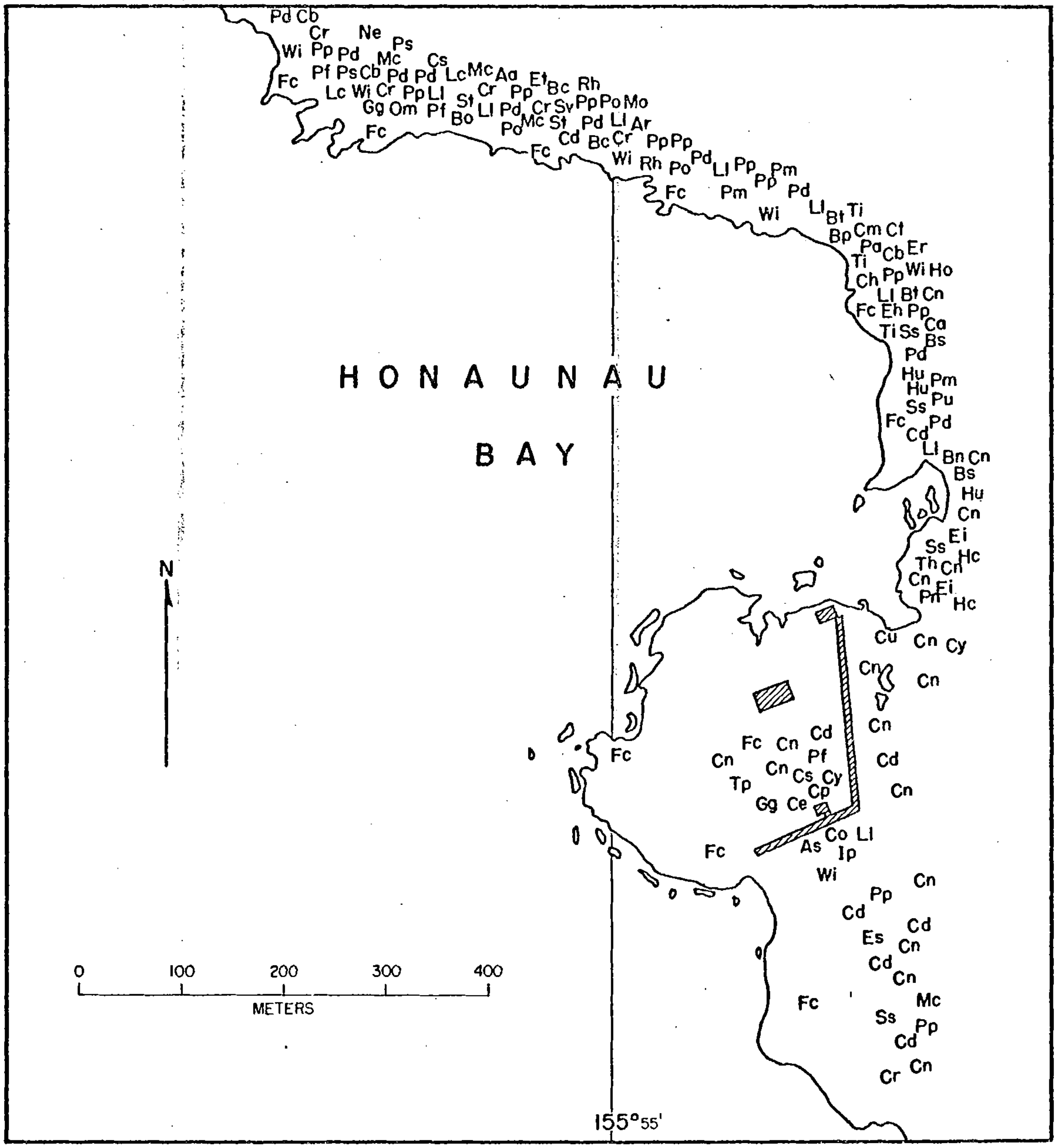

FIGURE 34. Shoreline vegetation at Honaunau Bay.

In general, however, it should be emphasized (Bryan, 1957) that except in the vicinity of the restored City of Refuge itself the vegetation in this region is very monotonous, thorny and introduced. Examples of plant life present at the time of Captain Cook (Table 43) consist of but isolated specimens among a sea of weedy exotics.

A residental area fronts the eastern shore of Honaunau Bay and the vegetation here was largely intentionally planted. The more common trees are plumeria (*Plumeria* spp.), coconut (*Cocos nucifera*), monkey pod (*Samanea saman*) and papaya (*Carica papaya*). The ornamentals include bougainvillea (*Bougainvillea* spp.), night-blooming cereus (*Hylocereus undatus*), Madagascar periwinkle (*Catharanthus roseus*), bryophyllum (*Bryophyllum tubiflorum*), air plant (*B. pinnatum*) and snow bush (*Breynia nivosa*). Most lawns are of Bermuda grass (*Cynodon dactylon*).

TABLE 43. Plants currently represented in the environs of Honaunau Bay which were present at the time of Captain Cook's arrival in the 1700's. "P" indicates that the species was probably brought to Hawaii by the Polynesians; "N" indicates that the species is probably native to Hawaii.

N or P	Scientific name	Common name	Comment
N	Psilotum nudum	moa	Common on open lava flows.
N	Nephrolepis exaltata	ni'ani'au sword fern	Common on open lava flows.
N	Polypodium pellucidum	"ae	Occasional on open lava flows.
N	Fimbristylis spp.	sedge	In pockets of sand on lava flows near coast.
P	Cocos nucifera	niu coconut	Common on the park grounds.
N	Peperomia leptostachya	'ala'ala-wainui	Occasional on open lava flows.
N	Cocculus ferrandianus	huehue	Scattered on open lava flows.
N	Waltheria indica	hi'aloa	Common on open lava flows.
N	Ipomoea indica	koali 'awahia morning glory	Common throughout, on open lava and in scrub.
P	Cordia subcordata	kou	One persists near the Great Wall, but is badly ravaged by insects.
P	Morinda citrifolia	noni	Occasional on open lava flows and in scrub. There are a number within the park grounds.
N	Ipomoea pes-caprae	pohuehue, beach morning glory	Occasional on sandy shorelines.
N	Heteropogon contortus	pili grass	Sparingly reintroduced on the park Palace Grounds and by the parking lot.
P	Artocarpus altilis	'ulu breadfruit	Rare on the north shore of Honaunau Bay. There was formerly a grove two miles north of the bay.
P	Thespesia populnea	milo	A specimen grows on the park Palace Grounds.

TABLE 43 (continued)

N or P	Scientific name	Common name	Comment
P	<u>Pandanus</u> <u>odoratissimus</u>	hala	Handsome specimens grow on the park Palace Grounds.
P	<u>Tephrosia</u> <u>purpurea</u>	'auhuhu	Occasional on open lava flows. Several were observed near the Great Wall.

SUMMARY AND CONCLUSIONS

Honaunau Bay is located near the middle of the Kona Coast on the island of Hawaii. Adjacent to its southern shore is the City of Refuge National Historical Park, established in 1961. Small and attractive Honaunau Bay is the principal natural feature at the park. It lies 2.5 miles south of Kealakekua Bay where Captain Cook was killed and a little north of the old village of Kookena where Robert Louis Stevenson did some of his writing.

The reconstructed temple, Hale-o-Keawe, lies at the water's edge and nearby is the restored stone edifice, Alealea Heiau. However, the park boundary extends only to the high tide mark on the southern shore of Honaunau Bay. The bay itself and the balance of its periphery are presently totally without protection. Both the central and north shorelines of Honaunau Bay lie outside the park, and in terms of scenic protection, preservation and archeological importance this is unfortunate. Archeologically, it is estimated at least one-third of the original village of Honaunau stood along the north shoreline.

The annual number of visitors (Table 1) to the park has doubled nearly three times in the last five years, from 38,664 in 1964 to 250,000 in 1968. Apart from this, two tourist vessels with capacities of 180 persons each make daily, nonstop excursions year round to Honaunau Bay from the tourist center at Kailua-Kona. Unlike most accessible areas in Hawaii, the Honaunau setting has, except for introduced weedy vegetation, largely biologically and physically changed but little since the arrival of Captain Cook in the 1700's.

Few places in Hawaii are of greater historical significance than Honaunau. For several centuries preceding the arrival of white man, Honaunau was the religious, cultural and political center of Hawaii. The City of Refuge is the ancestral home of Kamehameha the Great, the most famous member of the Hawaiian dynasties. It was a sanctuary for different losers and taboo breakers, and is believed to have been in operation before 1492. Concepts of refuge are part of the Polynesian culture. Hale-o-Keawe is the most sacred temple of ancient Hawaii and is the principal man-made attraction at the park.

Several suggestions have been offered as ways of preserving the bay and setting. All would bring Honaunau more fully under the control of those who would preserve it. One suggestion is purchase of the entire bay periphery, particularly the north shore. Another involves purchasing instead a scenic easement of the land. A third suggestion is to make a natural preserve of all waters inshore of a line drawn from Miana Point to Loa Point (Fig. 1), a distance slightly less than two miles. Establishing such a preserve would vastly aid in maintaining the beauty and natural importance of this wilderness area for the enjoyment of future generations, and, conversely, there is no reason at all to expect that this bay will not become irreversibly destroyed by pollution without protective measures. The implications of the present Kona Coast population influx cannot be ignored. The entire coast it would not seem is undergoing development at an astonishing rate, and terming the region a wilderness area is in itself already anachronistic and fanciful.

The ecological conclusions of the present study of Honaunau Bay relate to geological and hydrological conditions and to the algae (limu), plankton, corals, mollusks (e.g., sea shells), sea urchins (vana), crustacea (e.g., lobsters, crabs, shrimp), fish, porpoises, turtles and the surrounding land mass vegetations. Current situations are described for both land and marine populations, and land-sea relationships are discussed in terms of the sediment and other contents of the freshwater runoff.

At the present time, exploitation of the Honaunau habitat ranges from minimal to detrimental, and principally includes waste disposal and taking of coral, fish, mollusks and crustacea. There is an abundance of accumulated trash in shallow water fronting the populated eastern shore of Honaunau Bay, and coral is presently commercially gathered in Honaunau Bay for use in the tourist industry. Although fish are abundant here by comparison with populated areas of Hawaii, it was observed in the present survey that as one approaches uninhabited regions south of Honaunau, past Hookena, fish populations dramatically increase. Even more striking is the increasing frequency of crustaceans such as crabs and lobsters south of Honaunau. Much of this rich, pristine and unprotected area to the south is presently undergoing residential development.

No thermocline, or layering of large water masses, was detected above a depth of 400 feet. The current along this part of the Kona Coast was southerly during the period of this survey, its rate measured at 500 m/hr. The surface meter of water (Figs. 5 through 8) flushes directly outward at the flood tide and shifts southwesterly as the tide recedes. Movement is minimal near ebb tide, slowing near the eastern shore to 50 m/hr which differs from the rate outside the bay of one order of magnitude. As the tide rises the current quickens and several circular patterns are instituted. Flushing must be almost complete daily.

The topography of a bay affects its current system, and in the case of Honaunau Bay a very deep trench extends along the south-facing shore. The balance of the bay is relatively flat to a depth of 20 meters. This trench enhances the flushing of the bay. For instance, during a rising tide the surface meter of water flows to the region of the deep trench and then is carried out to sea at an accelerated rate. The trench, however, did not affect the surface meter of water at other tides.

A major consideration in this study was locating and testing points of freshwater seepage into the bay. No river mouths or estuarine situations are present, but the amount of brackish water, even measured after a prolonged dry period, is considerable and shown in Table 44 fertilizer high.

"Brackish water" here refers to percolation or leaching into the ground water from the surrounding land masses; its volume reflects the water table. The higher ground inland of Kealakekua Bay receives much more rainfall than does the bay itself. In a brackish situation the colder, less dense fresh water forms a layer on top of the sea water. This layer varies with the tide height, the rate fresh water percolates into the area, turbulence and waves. The rate of mixing in a sheltered area such as Keone-eli (see Fig. 4 for place-name designations), for example, is much slower than off more exposed Hale-o-Keawe.

The major brackish-water stations in protected areas of Honaunau Bay are also those stations receiving the greatest volume of freshwater percolation. These areas are Kapuwa'i and Keone-eli, and their lenses of brackish water converge in a common channel off Puuehu rock. The water here is very clear. Were there solid wastes present, even as

TABLE 44. Summary table of components measured in water from different stations in or near Honaunau Bay.

Station number	Salinity o/oo	Fecal bacteria per 100 ml	Nitrate nitrogen μg/l	Phosphate phosphorus μg/l
10-Head of Bay (north of 11)	32.5	4	74.0	19.3
11-Head of Bay (north of 12)	33.0	0	18.2	8.9
12-Kapuwa'i shore	5.5	9	729.2	141.1
12-Kapuwa'i 30 meters from shore	20.0	15	193.5	47.8
13-Keone-eli 20 meters from shore	26.5	23[a]	129.7	47.1
14- Royal Fish Pond	8	43	232.2	65.4
15-Hale-o-Kiawe	31	9	36.4	16.5
17-Alealea Heiau Pond	34.5	3	2.6	4.3

[a] In one sample there were 460 fecal bacteria per 100 ml.

particulate matter, or a high plankton population, the water would be turbid and one would expect mussels or other detritus feeders in abundance. That such conditions do not prevail is surely due to the efficiency of the sand filtering of the polluted effluent reaching these two places and the high, probably semidiurnal, flushing rate of the bay.

The present study of currents points up the exposed nature of Honaunau Bay rather than demonstrating protected areas. Whereas the brackish inlet Keone-eli appears quite sheltered to the eye, during both falling and rising tides the water mass shifted from the fringes of this area into the bay proper at rates from 100 to 200 m/hr. The nearby deep trench extending to almost the head of the bay is instrumental in this flushing pattern. Relative to the rest of the bay, however, the inlet is sheltered, and this sheltering slows mixing rates of the percolating ground water and mineral and organic constituents it carries with the sea water.

Perhaps one of the reasons Honaunau Bay is as unchanged as it is is its apparently high flushing rate. In a recent study of Kealakekua Bay, sheltering was dramatically emphasized. Movement along the periphery of this much larger bay averaged only 50 m/hr, and, furthermore, the current buoys tended to remain within the confines of the bay during the entire tide cycle. In line with this, the incidence of beaching was much higher and flushing less in Kealakekua.

Fifteen discrete points of freshwater entry (Fig. 9) into Honaunau Bay were isolated. Of these, however, only the stations at Kapuwa'i and Keone-eli were other than exposed. In order to judge how clean the brackish water is, testing was conducted to determine levels of coliform bacteria, nitrate, nitrite, phosphate and ammonia. The values obtained were then compared with the public health regulations of the State of Hawaii regarding water quality standards. It was shown (Table 44) that the entire bay meets standards for "AA Water" except for the region near Keone-eli which meets the standards for only "B Water."

"AA Water" is pristine, characteristic of a wilderness region. "A Water" is less so, but is regarded as completely suitable for swimming and recreational use. "B Water," on the other hand, is thought too contaminated for swimming, and suited instead for such use as a small boat harbor.

The region off Keone-eli is turbid and contains even visible suspended matter. It is the only turbid area in the entire bay. The contamination is from two cesspools situated 34 m from the sandy-beach shoreline. One public restroom in use today was recently erected by the Park Service as part of a new visitor's center. The State had condemned the original cesspool as inadequate to service the burgeoning tourist industry, but has granted a temporary, 2-year approval for the present system. It is thought that in 1971 funding will be available to institute a sewage treatment plant.

Not only is Keone-eli cove contaminated, but this is the most popular bathing area in the entire bay, favored by those wanting to avoid the more exposed, deeper waters of the bay proper. Park records state that several thousand swimmers use this cove annually. As indicated above, this cove does not meet State sanitary water standards for a swimming beach.

Mollusks or sea shells favoring brackish water are very abundant in Keone-eli and Kapuwa'i and principally include pipipis (Theodoxus neglectus) and mussels (Isognomon californicum). These species are also very common at Kaawaloa Cove, the most contaminated region in Kealakekua Bay which is likewise sheltered and brackish.

Plankton tows were carried out in both Honaunau Bay and Kealakekua Bay. The mean zooplankton biomass near the surface is greatest in Honaunau Bay. The densest population in Kealakekua Bay was 146 mg wet weight zooplankton per cubic meter at Kaawaloa Cove, whereas an average of 187 mg/m^3 was collected at the head of Honaunau Bay. This indicated that of the two bays, Honaunau is the more productive.

The underwater topography at Honaunau Bay was described, and four 100-meter transects (Fig. 12) laid out by SCUBA divers in order to quantify the data. The shoreline slope is relatively gentle to a depth of 20 meters, the limit of visibility. This is similar to the situation at Kealakekua Bay. However, the slope is not outward but northwest due to the deep, sandy-bottom trench which extends along the north shore to nearly the head of the bay and widens southerly with increasing depth. As pointed out previously, this trench speeds mixing and flushing of material entering the shoreline. Porpoises and occasionally sharks enter the bay along this trench, but the sandy bottom does not support significant populations of Kona crabs such as were observed in larger and deeper Kealakekua Bay.

In general near shore the bottom is covered with an assortment of boulders and smaller fragments which lessen in abundance as one progresses seaward. The dominant recognizable organisms are coelenterate corals, fishes and sea urchins. Beyond six meters the coral cover is nearly 100 per cent, covering all rocky areas so that one observes but a sea of colorful coral mounds amongst sporadic patches of sand.

The visible macroscopic algal material (seaweed or limu) is almost entirely intertidal. Except for spots of mat-like crusts of algae on boulders in some areas, no benthic algae at all are generally observed at depths greater than two meters save for a single red alga, Tolypiocladia glomerata, which is very common in the interstices of the finger coral (Porites compressa). As this situation is common along the sides of the deep trench, the north shore of Honaunau Bay superficially resembles Kaawaloa Cove with similar dominant biotic populations along a steep slope. The brown alga Turbinaria ornata was frequently recorded from Kealakekua Bay in the summer and fall growing in interstices of castle coral (Porites pukoensis), but during the present survey, conducted in March, it was not observed in Honaunau Bay. Instead, the green alga Halimeda discoidea was uncommonly seen in such interstices.

As indicated above, the benthic seaweed population is sparse. To the casual observer it might appear absent. The only sublittoral area dominated by benthic algae is Keone-eli cove which is likewise the only contaminated area in Honaunau Bay. To a depth of two meters the substratum at Keone-eli is blanketed by a red alga, Gelidium sp., covered with massive diatom filaments. The floor looks brownish and appears silty from the diatoms, and the Gelidium is only apparent after the fronds have been shaken to remove them. There is no reason to believe that if pollution becomes intensified algal beds will not proliferate further. The southern and eastern portions of the bay appear particularly suitable for heavy cover. At the present time, however, it appears that the normal benthic algal role is replaced by zooxanthallae (dinoflagellates) in the extensive coelenterate coral beds.

In Waikiki, by comparison, seaweeds occur in various quantities, and that they are hard to find in any quantity in Honaunau Bay is related to low fertilizer concentrations. Although present now in only token amounts, the usual species complement for the rest of Hawaii can perhaps be found here and with continued pollution could replace the corals.

The development of a pollution-type marine community at Honaunau Bay would mean loss of much of the present Hawaiian marine life, and in few other areas is this marine life more readily accessible to the itinerant. During the present survey, pollution communities were observed in nearby, built-up Kailua Bay and Keauhou Bay. A familiar example on Oahu is the splash of green in front of the bathhouse at Hanauma Bay. The principal among these green pollution indicators is the presence of an algal community dominated by the genus Ulva, presently observed intertidally at Honaunau Bay. Larger green areas of this sea lettuce, often becoming off-white or yellowish in part, can be expected to develop if further significant amounts of fresh water and fertilizer percolate into the bay, and if processed sewage is included.

A marine shore area in balance coming to receive quantities of fertilizer flushed in with fresh water will alter in adapting to the new conditions. The expected pattern is for a series of near-irreversible changes to occur. Among first changes to be seen are in the microscopic algal organisms, for example, in the phytoplankton and in those essential to the larval animal stages and those utilized as zooxanthellae by coral adults. The results are newly dominant species of the short-lived, frequently reproducing kinds. In this case, they will be those relatively insensitive to or stimulated by the addition of fresh water and the fertilizers derived from sewage. In the tropics the benthic species are usually members of the Ulvaceae; Entermorpha if a steady supply of fresh water is involved, or Ulva if the fresh water is less or periodic and contains increased nitrogenous wastes. Thus, it is that a splash of green from these seaweeds in front of a residence or bathhouse indicates pollution.

With the advent of intensified sewage disposal at Honaunau Bay and such populations as the above appearing, the natural food for the native organisms decreases. That is, though the total amount of food available may increase, the animals such as the corals which are very restricted in their diets find their food decreasing. Thus, such corals, fishes and other animal populations would decrease to the extent they did not consume the new algal population or the pollution material directly. Actually the Ulva fasciata community to be expected with further pollution is usually strangely devoid of animal life or much of any living material other than the seaweed Ulva itself. Many explanations have been offered for this, but two are wide variations in the oxygen content of the water and the production of toxic materials, such as dimethylpropiothetin derivatives, which do function to the exclusion of animals or their food.

Alteration of any natural habitat such as Honaunau Bay will encourage success of exotics. This is the general explanation for the lack of native plant and animal life below about the 1500-foot level on Oahu. Exotic seaweed species such as Acanthophora spicifera, Ulva reticulata and the endemic Dictyosphaeria cavernosa have become dominating elements in Kaneohe Bay, Oahu, within the last 20 years accompanied by the disappearance of other seaweeds and of those fish species which fed upon them.

New plantings on land are usually well watered and fertilized and most of that fertilizer percolates to the nearby sea. Even apart from the fertilizer, as the plants grow and photosynthesize much of the material may wash out of the plant into the ground water and, to the extent not destroyed by biological activity in the soil, end up in the sea as fertilizer materials.

The coral population present is unique to this area. A marked zonation of the coral to a depth of 20 meters is described. This situation and these zones are generally found in Honaunau Bay largely as it is in Kealakekua Bay. The first zone extends to a depth of five meters and is dominated by Pocillopora meandrina. Zones two and three extend to a depth of 15 meters and are dominated by castle coral (Porites pukoensis). This coral which forms enormous mounds or castles is particularly colorful in clear water due to the presence of bright green or yellow or even bluish photosynthetic microorganisms (zooxanthallae). However, towards

Keone-eli where the water is noticeably turbid, the colonies are most often brownish and dull in color.

Zone four extends to 20 meters depth and is dominated by finger coral (*P. compressa*). This coral is abundant at greater depths in Honaunau Bay, but also frequently grows in waters less than four meters deep. It is somewhat curious as such shallow records for finger coral were not observed in other bays. It was also pointed out (Fig. 23) in the present survey that of all the corals in Honaunau Bay finger coral appears to be most sensitive to local variations in ecological conditions. Finger coral is easily broken, and is usually restricted to more sheltered and deeper habitats.

The extent of vertical coral distribution was thought limited by light penetration, temperature and possibly food. It was brought out that the species of coral present are presently in a very delicate ecological balance, a balance thought to be principally maintained by low phosphate in the environment, and by lowered salinity and temperature due to the presence of fresh water. Some corals do not tolerate higher levels of phosphorus than found in the open tropical seas and, of course, sewage outfalls are an extremely rich source of phosphate salts.

Two items previously noted (Table 44) are that the Royal Canoe Landing (Keone-eli) is contaminated by seepage from two cesspools, and that Honaunau corals appear to tolerate only low levels of phosphate, a major sewage constituent. In line with this, the beds of finger coral (*Porites compressa*) off Keone-eli are at the present time mostly dead. Their worn bases are abundantly present, but are now scarcely recognizable and encrusted with a second coral species, *Pavona varians*. This condition is not present elsewhere in Honaunau Bay. A similar situation dominates the scene off Waikiki on the island of Oahu, where historical accounts tell us coral gardens flourished formerly.

There are noteworthy features exhibited by the marine molluscan fauna (sea shells, etc.) at Honaunau Bay, and these are enhanced from a general interest standpoint by the sparkling clear waters and exceptional visibility usually experienced in the bay.

In terms of percentage composition of species Honaunau Bay has a proportion of gastropods (cowries, cones, etc.) to bivalves (clams, oysters, etc.) of 89:11 (or 89 per cent gastropods). A recent study at nearby Kealakekua Bay yielded the same proportion. This appears to be higher than has been measured elsewhere in the Hawaiian Islands, which has an overall proportion of 82:18. The ratio in strongly contaminated Kaneohe Bay, Oahu, is 80:20.

Bivalves are filter feeders and hence tend to increase when pollution increases, whereas a gastropod population is indicative of unsilted conditions. Hence, as an area becomes contaminated one expects the ratio to decrease by the appearance of large numbers of bivalves such as mussels, and extinction of various gastropod species of cowries and cones. It is known that many gastropods which used to be collected in Kaneohe Bay are no longer present, and the exceedingly high percentage for Kealakekua Bay is evidence for the unspoiled conditions that exist there. There is also here a high percentage of epifaunal mollusks which indicate clean water over infaunal mollusks which thrive under siltier conditions.

It is felt that at the present time the mollusk population is in a delicate ecological balance and disturbances, such as increased nitrate and phosphate salts leaching into the bay, would result in an imbalance of the community and possible extinction of some species from the area.

In terms of overall biomass, coral, fish and sea urchins are the top three animal groups in Honaunau Bay. Corals provide shelter for both adult and juvenile fish and urchins. Urchins and some fish species compete with each other for algae, and also prevent algae from smothering the coral growths. An imbalance in any of these three groups will in all likelihood drastically alter populations of the other two.

The major sea urchins by order of importance in Kealakekua Bay are the slate pencil urchin, <u>Heterocentrotus</u>, and the vanas, <u>Echinothrix</u>, <u>Echinometra</u> and <u>Tripneustes</u>. The abundance and distribution of <u>Echinometra oblonga</u> and <u>E. mathaei</u> are similar in Kealakekua Bay and Honaunau Bay. However, the other three genera are considerably less common in Honaunau Bay. In fact, <u>Echinothrix</u> and <u>Tripneustes</u> were not recorded frequently enough to yield significant results. <u>Tripneustes</u> is the most abundant urchin at visible depths exceeding four meters in two nearby polluted bays, Kailua and Keauhou. At depths of less than two meters, <u>Echinothrix diadema</u> is the most abundant urchin in Keauhou Bay while

Heterocentrotus is most abundant at this depth in Kailua Bay.

Echinometra mathaei is the most abundant urchin in Honaunau Bay. The average density for all urchins in Honaunau Bay is 9.0 per square meter. Excluding Echinometra the average density is 2.3 per square meter. These values are comparable to densities in Kaawaloa Cove and are higher than any other areas in Kealakekua Bay. As was found in Kaawaloa Cove, urchin biomass decreases quickly with increasing depth. Due to the lower densities of Echinothrix and Heterocentrotus, the absolute values are much lower in Honaunau Bay than at Kaawaloa Cove.

Although the small urchin, Echinometra mathaei, is most abundant, in terms of overall biomass Heterocentrotus is the most important urchin in Honaunau Bay. It is, however, significantly less common than in Kealakekua Bay. These colorful urchins are often prized as souvenirs, and the spines are made into wind chimes for sale by local merchants. This great abundance of slate pencil urchins does make the Kona Coast unique as excepting isolated other sites such as Molokini Reef on the island of Maui. Heterocentrotus is not common in Hawaii.

It was determined from secondary productivity rates that the turnover rate of Kealakekua Bay urchins is more than five years and probably close to ten years. This gives an indication of the rather long time it would take a community to repair itself if harvested or otherwise damaged.

The factors affecting distribution and abundance of urchins are often listed as depth, substrate, exposure to waves, food, animal behavior and chance. With these in mind the distribution and densities of urchin populations in several localities were plotted. However, the finding was that the urchin populations were correlated with none of the above measurable parameters, and that chance probably played a major role in their establishment. What this means is that were the urchin community to be wiped out, in all likelihood something different would come back. The present, unique assemblages probably would not return.

In postulating chance as a major determining factor in urchin distribution it was noted in this study that certain features were not associated with physical or biological factors. For example, at Napoopoo Light, Echinothrix was the dominant urchin, yet this species was not present at a physically similar station one mile south of Honaunau Bay.

Tripneustes was also different between these two stations and, as noted above, the slate pencil urchin, *Heterocentrotus*, is highly important in most sites examined along the Kona Coast yet is generally uncommon in other areas of the Hawaiian island chain.

Whether *Heterocentrotus* has always been rare in other areas is not known for certain. Edmondson (1946) lists *Tripneustes* and *Echinothrix* as common forms and says that *Heterocentrotus* "frequents the outer border of the reef platform, but young specimens are sometimes seen near the shore." This applies mainly to Oahu. The impression is given by Edmondson that *Heterocentrotus* certainly has not been a dominant element of the urchin fauna for the past 70 years, if it ever was.

Urchins form a segment of the shallow water communities that probably receives a large portion of the energy from primary production by algae. The urchin population in Kaawaloa Cove does decrease with depth or darkness, so presumably its numbers do depend rather directly upon primary productivity.

Predictions of the results of human activities to the urchin fauna must naturally be very tentative. However, a number of most probable results can be suggested. First, anything that would tend to eliminate the living coral would probably change the species composition of urchins. The most likely change would be reduction of *Heterocentrotus* and a possible increase of *Tripneustes*. With the associated decrease in bottom relief, *Echinothrix* would also be expected to decrease.

Effluent from cesspool percolation would increase turbidity in the bay and, through light attenuation, would decrease productivity with depth. Such processes are known to cause sharper urchin zonation with fewer at lower depths. The net result would in all probability be an overall decrease in urchin biomass.

Because it presently is not known whether the abundance of *Heterocentrotus* on the Kona Coast represents an ecological climax situation (the result of many communities succeeding each other in ecological progression toward equilibrium), or is instead a community formed by factors of chance, the recovery of a bay after a marked biotic change is difficult to predict.

If the area is a climax community, it would probably return to its original state. On the other hand, if the species composition were established by chance, then severe damage would not necessarily be reparable. From the data presented in this study, it appears likely that chance is important.

It was pointed out that a veritable sea-life exhibit in the form of a shallow, protected inlet is present just west of Hale-o-Keawe, and it is recommended that this easily accessible biological laboratory and marine display be preserved for public edification and enjoyment. It contains incredibly large populations of at least five species of sea urchins, colorful seaweeds and assorted other tropical sea life. The inlet could easily be incorporated into the park trail system.

The only larger crustacean seen in numbers was the "cleaning shrimp," Stenopus hispidus. The population of spiney lobsters (Panulirus japonicus) in Honaunau Bay was thought scant considering the amount of cover. As pointed out above, their absence is apparently due to factors of human foraging as their numbers sharply increase moving south toward uninhabited regions. Kona crabs (Ranina serrata) are commonly trapped at sandy depths of 60 meters off Alahaka Bay.

Two underwater, 750-foot stainless steel transect lines were established in Honaunau Bay and five in Kealakekua Bay. Over these lines fish counts were made quarterly. It was determined (Table 11) that Honaunau Bay has an average of 364 pounds and Kealakekua Bay has an average of 233 pounds of fish per acre. The reason Honaunau Bay has a higher biomass of fish than Kealakekua Bay is because the Kealakekua substratum at greater depths is largely sandy and will not support fish in numbers.

The average count of 346 pounds of fish per acre at Honaunau Bay is higher than has been recorded elsewhere in the Hawaiian Islands. The second highest average is at a transect placed off Niihau in a pristine area particularly favorable for fish. Here the average is 275 pounds per acre. Off Waikiki, by comparison, an average of only 148 pounds of fish per acre have been counted.

One hundred and twenty-one different species of fishes were observed in Honaunau Bay and Kealakekua Bay, of which 98 species were found in Honaunau and 110 in Kealakekua; 87 species were recorded on all

TABLE 11. Pounds per acre of fishes in Kealakekua Bay and Honaunau Bay, Hawaii.

	Kealakekua Bay					Honaunau Bay		
Survey	Station 1	2	3	4	5	6	7	
June	151	163	-	175	111	276	324	
Aug.	267	204	102	102	58	274	138	
Oct.	283	385	669	107	163	603	306	
Feb.	358	548	167	201	122	599	388	
MEAN	265	325	313	146	114	438	289	270

* Station 3 established in August.

transects, and 13 species were present on all transects during every survey. This is not surprising for Honaunau Bay is minute in size comparatively. The most common fish species are yellow tang (Zebrasoma flavescens) and kole (Ctenochaetus strigosus).

Numerous fish species are commonly recorded in Honaunau Bay but not in Kealakekua Bay, and vice versa. This reflects ecological niches to which certain species are adapted. For example, Station 6 (Fig. 30) is situated on a steep shoulder or drop-off blanketed by finger coral (Porites compressa) with the red alga, Tolypiocladia, growing in the interstices. No other station has quite this exposure and topography, and two species in great abundance here but uncommon elsewhere are Acanthurus guttatus and Naso unicornis. Similarly such fishes adapted to special conditions are associated with each of the various transects. This is an example of the delicacy of ecological niches, and altering the environment in some way can easily trigger a series of minor changes with the cumulative effect of destroying such niches and the marine life associated with them.

Kole (Ctenochaetus strigosus) is a common species of fish throughout the islands whereas Hawaiian kole (C. hawaiiensis) is common in Honaunau Bay, but uncommon in most areas of the Hawaiian Islands. These species live between boulders and coral mounds and feed on microorganisms. Just why the latter is common here is not known.

The shark population in nearby Kealakekua Bay was quantitatively estimated as moderate. None was seen in Honaunau Bay. Turtles were reported singly and in pairs within Honaunau Bay every third day or so by members of the survey teams.

There is a resident school of spinner porpoises (Stenella sp.) in much larger Kealakekua Bay. From 30 to 80 members are variously estimated, and the animals are so tame that consideration has been given to training the school in the wild as a tourist display and for use in scientific research. During the present survey, members of the school were often observed in Honaunau Bay during the morning hours. They approached the head of the bay, but always remained in the vicinity of the deep trench along the south-facing shore.

As indicated above, there is an intimate relationship between a shoreline and conditions on nearby land masses. Land use is reflected in the nature of the freshwater runoff, and this in turn reflects on the marine biota subjected to it. For this reason, a study was undertaken of the present vegetation types on the land surrounding Honaunau Bay.

Throughout the region the vegetation predominantly consists of species introduced to Hawaii since the time of Captain Cook. The only area where plants previously present are at all common is on the cleared and re-planted grounds of the City of Refuge N. H. P.

A recreation of the pre-European scene has been undertaken at the park with some success. However, the City of Refuge project has involved the use of herbicides, and caution should be exercised whenever large doses of herbicides are employed to avoid permanent buildups of residues in the soil, and especially to avoid runoff into Honaunau Bay where significant ecological changes might occur. Mechanical means of control are preferred whenever feasible.

Apart from cleared areas, the predominant vegetation type in the environs of Honaunau Bay and Alahaka Bay today is a mixed, thorny scrub forest of opiuma (Pithecellobium dulce) and ekoa (Leucaena leucocephala). Another member of the pea family, kiawe (Prosopis pallida), is also very abundant here. Some of the botanically more interesting plants persisting in the environs are listed on Table 43. In conclusion, however, there appears no compelling botanical reason for preserving the vegetation at Honaunau in its present weedy state.

There is an opportunity here to observe the unexplained phenomenon of differential growth of plants on the different lava flows. A given species will often be abundant or grow to large size on one flow while on an adjacent flow it may be absent or small in size or numbers. These phenomena are often without correlation with age or any apparent physical conditions.

Native shore birds that inhabit the Honaunau region are the plover, wandering tattler and the ruddy tern stones. Common introduced birds are the myna, doves, cardinals and white eye. The only native mammal in the park is the Hawaiian bat. The mongoose was introduced into the Kona area many years ago and is quite prevalent at the park.

In conclusion, Honaunau Bay and its shores are of national monument quality now for the marine life. This situation is threatened by present practices and population pressure largely of economic sorts. Both of these threats are small and could be controlled by enforced legislation and pollution control measures to the end that an unusually attractive marine park remains available to Hawaii's people and their visitors from abroad.

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